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Sedimentology and Volcanology of Selected Tectonized Stratigraphic Units, Southern Birch–Uchi Greenstone Belt, Uchi Subprovince

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by

J.R. Devaney

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Abstract

As a contribution to projects investigating the geological evolution of the western Uchi Subprovince, this report presents results of reconnaissance-scale remapping of selected tectonized (meta)sedimentary and fragmental (meta)volcanic units that comprise parts of the southern Birch–Uchi greenstone belt. Volcaniclastic and sedimentary facies are described and interpreted in a more detailed and specialized fashion than in most previous studies. Such knowledge is directly relevant to assessing the potential for Cu-Zn and Au mineralization in the greenstone belt.

Most of the studied lithofacies units are volcaniclastic parts of the Confederation assemblage (deep water deposits of volcanic-sedimentary, arc-related basinal settings) or younger synorogenic conglomeratic units. The nine selected areas/units described are those at:

1. eastern Narrow Lake (turbiditic and volcaniclastic facies suites);
2. Woman Lake (west-younging fluvial polymict conglomerate and sandstone facies, and subaqueous wacke-siltstone facies);
3. southwest arm of Confederation Lake (volcaniclastic facies);
4. South Bay of Confederation Lake (felsic volcanic facies at and near the former South Bay volcanogenic massive sulphide minesite include crystal tuff "porphyry," spherulitic lava flows, and monotonous tuffs; correlative highly altered rocks are present to the south);
5. Lost Bay of Confederation Lake (significant evidence of sedimentary deposition, and minor evidence of directly volcanic deposits);
6. Uchi Lake (equivocal "tuff-wacke" volcaniclastic facies);
7. Sundown Lake (both fluvial and resedimented (turbiditic) deposits appear to be present, clastic facies very similar to the conglomeratic units exposed elsewhere in the Birch–Uchi greenstone belt and interpreted as the infill of late orogenic pull-apart basins; clasts identical to the composition of an adjacent spherulitic volcanic unit are notable as locally sourced clasts);
8. Cromarty Lake (conglomerate to siltstone facies); and
9. Bertha Lake (highly metamorphosed wacke).

The volcaniclastic facies in four units and/or areas (#3 to 6, above) are typical of the deposits of Archean subaqueous volcanic successions, with some interesting new lithofacies details, but the exposures offer little specific information regarding the larger-scale internal stratigraphic architecture (geometry) of any discrete Confederation assemblage volcanic-sedimentary basins. Reliable recognition of basinal architecture and the stratigraphic gradation from pyroclastic material to "volcaniclastic" deposits more reworked by sedimentary processes depend on good continuity of exposure and good stratigraphic resolution (e.g., multiple correlations within a thick stratigraphic unit, and correlation from one tectonized unit to another), both of which are lacking in the Birch–Uchi greenstone belt.

The three epiclastic conglomeratic units studied (#2, 7, 8, above) are interpreted to be postarc, late orogenic strike-slip ("pull-apart") basins similar to those in the northern Birch–Uchi greenstone belt, except that the postarc context is less certain for the Woman Lake conglomeratic unit, and the conglomeratic units at Woman and Sundown lakes would have been controlled by the predominantly sinistral, late orogenic, faulting previously documented for the southern Birch–Uchi greenstone belt (versus the dextral faulting interpreted for the northeast part of the belt).

Regarding the regional stratigraphic context of the South Bay volcanogenic massive sulphide Cu-Zn deposit, structural complexity and poor continuity of exposure limit stratigraphic resolution (application of volcanic facies and ore deposit models) both near the mine and regionally. Some workers have suggested a "back-arc basin" setting for the deposition of the Confederation assemblage, based on geochemical (geodynamic) signatures, but because no active arc versus back-arc (paleo-)basinal geometry or stratigraphic relationships have been demonstrated, the supposed back-arc context might be better considered as intra-arc rifting.

Regarding the potential for mesothermal gold deposits in the Birch–Uchi greenstone belt, interpretations of postarc, late orogenic strike-slip basins (Timiskaming-type sequences) such as those described herein imply the regional importance of strike-slip faults (and, at depth, related shear zones), which are commonly thought to have been important in focussing the synorogenic flow of auriferous fluids within tectonized greenstone belts.

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J.R. Devaney

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Introduction

Although Archean greenstone belts have been the subject of intense study, the sedimentary aspects of their history (Ojakangas 1985; Williams et al. 1992; Eriksson et al. 1994; Windley 1995; Devaney 2000) have often been relatively neglected compared to studies of Archean volcanic, plutonic, and metamorphic rocks and related geochemical and structural aspects. Recent reviews have noted that "stratigraphic studies (sedimentological and volcanological) contribute significantly to the understanding of [Archean] greenstone belt evolution, because they prove the conformity of stratigraphic and tectonic styles through time" (Eriksson et al. 1994, p.80) and "there are rich rewards to be made by modern sedimentologists who dare to venture into the little-studied territory of Archaean sediments!" (Windley 1995, p.368).

In this light, sedimentological studies of parts of greenstone belts (or orogenic belts) within the Superior Province can be seen as an important component of multidisciplinary efforts to deduce the sequence of processes that is recorded in these rocks. As a contribution to the ongoing multiyear NATMAP project investigating the geological evolution of the western Uchi Subprovince, this report presents results of reconnaissance-scale remapping of metasedimentary and fragmental metavolcanic units that comprise parts of the southern Birch–Uchi greenstone belt (Figures 1, 2, 3). Detailed examination of the better exposures (mostly shoreline outcrops) has provided an improved database for interpreting the depositional paleoenvironments and tectonic history of the studied supracrustal units, knowledge which will be useful in the forthcoming reassessment of the Birch–Uchi greenstone belt's geological development and economic mineral potential. Also, the sedimentological aspects of some of the stratigraphic units in the Birch–Uchi greenstone belt are broadly relevant to an improved general understanding of Archean synarc volcaniclastic successions and postarc Timiskaming-type sequences (Devaney 1999b,c,d, 2001)

Stott and Corfu (1991) reviewed the geology of the Uchi Subprovince; their summary includes discussions of some of the localities in the Birch–Uchi greenstone belt commented on below. More recent studies concerning the stratigraphy and structure of the Birch–Uchi greenstone belt are those by Devaney (1997, 1999a,b, 2001), van Staal (1998), Borowik et al. (1999), Crews (1999), Crews et al. (1999), and Rogers et al. (1999, 2000). Some fundamental aspects of the stratigraphy of the Birch–Uchi greenstone belt are being revised by N. Rogers (Rogers et al. 2000); based on geochemical data and new geochronological data, some supracrustal units previously considered to be part of the Woman assemblage are now thought to be part of the much younger 2.74 Ga Confederation assemblage (Rogers et al. 2000; regarding the assemblages, see below, and Stott and Corfu 1991).

These recent and ongoing studies (above) are producing some: a) disagreements over the basic descriptive aspects of certain lithostratigraphic units; b) results that, for a given rock unit, are inconsistent from study to study; and c) interpretations that are in conflict with those of past studies. Therefore, before the puzzle of the region's geological evolution can be solved, a clearer view of what the individual puzzle pieces look like is needed, and the basic descriptive data and interpretations listed below attempt to help in this process.

Parts of this report are taken from previously published sources (Devaney 1998, 1999e, 2001) and are re-presented herein with some additions and modifications.

LOCATION AND ACCESS

The studied parts of the southern Birch–Uchi greenstone belt described herein (e.g., Woman Lake to Uchi Lake) are located about 75 to 95 km east of the town of Red Lake in northwest Ontario. Woman and Confederation lakes are accessible from the South Bay mine road. Fly Lake is accessible from a power line, at a short distance east of the South Bay mine road. More remote sites, such as Uchi and Sundown lakes, are best accessed via float plane from Red Lake, Ear Falls, or the lodges along the South Bay mine road. (Regarding Uchi Lake access, routes along both an old road from Lost Bay to Uchi Lake and the power line east of the South Bay mine road were blocked by impassable swamps and ponds in 1999.) Commercial fly-in fishing camps and private cabins are maintained on most of the larger lakes in the belt.

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BIRCH–UCHI GREENSTONE BELT OVERVIEW

The Birch–Uchi greenstone belt (*see* Figures 1, 2) is an arcuate, tectonically complex portion of the Uchi Subprovince contiguous with and located between the Red Lake and Meen–Dempster parts of the Uchi Subprovince (Stott and Corfu 1991). Previous studies of the southern part of the Birch–Uchi greenstone belt (Nunes and Thurston 1980; Gupta et al. 1982; Thurston 1985; Stott and Corfu 1991) revealed a long (ca. 3.0 to 2.7 Ga), episodic history of crustal development. Based on general bedrock mapping (Pryslak 1971; Thurston et al. 1974; Johns 1979a,b) and volcanologically oriented mapping, lithogeochemistry, and radiometric dating (Thurston 1984, 1985; Stott and Corfu 1991), the supracrustal rocks of the belt were subdivided into three major cycles, which were soon refined into the triad of the Balmer, Woman, and Confederation assemblages (stratigraphic group-scale units, listed in order of decreasing age). This three-part subdivision of tectonized assemblages was applied to most of the Uchi Subprovince by Stott and Corfu (1991). The Confederation assemblage is thought to be a continental margin (Andean-type) arc succession (Stott and Corfu 1991; Stone 1998), including intra-arc rift basin deposits (Hollings 1998; Rogers et al. 1999), versus the less certain tectono-stratigraphic context of the other assemblages. Documentation of the geochemical characteristics of the Confederation assemblage felsic volcanic rocks at and near the former South Bay Cu-Zn mine was part of the early efforts leading to the identification of "F3" rhyolites (Thurston 1981; Campbell et al. 1984; Lesher et al. 1986).

Workers performing recent and ongoing studies of the southern Birch–Uchi greenstone belt (Rogers et al. 1999, 2000) and the Red Lake greenstone belt (i.e., the western Uchi Subprovince NATMAP Project: Sanborn-Barrie et al. 2000) have proposed some modifications and additions to the Balmer–Woman–Confederation tectono-stratigraphic scheme. As discussed herein and elsewhere, some relatively small conglomeratic units likely form a synorogenic (postarc), discontinuously distributed, post-Confederation assemblage in the Birch–Uchi greenstone belt (Devaney 1999a,b,e, 2001). Radiometrically dated plutons within the Birch–Uchi greenstone belt are of post-Confederation assemblage, ca. 2725–2700 Ma age (Beakhouse et al. 1999).

The following reports and papers summarize the geology of the surrounding areas to the:

1. *north and northeast*: the northern part of the Birch–Uchi greenstone belt (Thurston 1986a, Good 1988; Beakhouse 1989, 1994; Beakhouse et al. 1999; Devaney 2001) is an area of less linear, likely more structurally complex, supracrustal units than to the south; farther north, the belt is bounded by the Berens River Subprovince (Stone 1998; or "North Caribou Terrane" of Thurston et al. 1991)
2. *east*: the Jeanette Lake Granitic Complex (Wallace 1983; Beakhouse 1989); farther east is the central Uchi Subprovince (Stott and Corfu 1991; Stott 1996);
3. *southeast*: the Slate Lake area (Williams 1988; Bowen 1989), which in map view is geometrically separate from the main arcuate (concave to southeast) bend portion of the Birch–Uchi greenstone belt, but likely contains similar or correlative stratigraphic units;
4. *south and southwest*: the supracrustal segment linking the Red Lake and Birch–Uchi greenstone belts (Wallace et al. 1986; Stott and Corfu 1991; Figure 6.3; for results from drilling by Noranda Inc., see Smith 1999); farther south, the Uchi Subprovince is bounded by the western English River Subprovince (Breaks 1991; Breaks and Bond 1993; Corfu et al. 1995); and
5. *west and northwest*: the western part of the Birch–Uchi greenstone belt (Thurston 1980, 1984, 1985; Rogers et al. 1999, 2000) and the Trout Lake batholith (Noble 1989); farther west is the Red Lake greenstone belt of the western Uchi Subprovince (Stott and Corfu 1991; Tomlinson et al. 1998; Sanborn-Barrie et al. 2000).

Details on specific mineral occurrences and properties are available elsewhere, in previous reports and through the Earth Resources and Land Information System (ERLIS). Descriptive details of gold (and other economic mineral) occurrences throughout the Birch–Uchi greenstone belt are summarized from previous reports in the compendium by Parker and Atkinson (1992). Volcanogenic massive sulphide mineralization in the area continues to be of interest (Smith 1999; Parker 1999a,b).

PRESENT STUDY AND RELEVANCE TO POTENTIAL MINERALIZATION

The main purpose of the present report is to describe and interpret selected Archean bedrock units of fragmental volcanic (volcaniclastic) and sedimentary facies in the southern Birch–Uchi greenstone belt (units in Figure 3) in a more detailed and specialized fashion than in previous studies. Such knowledge is directly relevant to assessing the potential for Cu-Zn and Au mineralization in the greenstone belt.

For example, study of the volcanic and related clastic and chemical sedimentary facies present, and any associated synvolcanic alteration provides valuable information about the potential for volcanogenic sulphide mineralization correlative with that of the former South Bay Cu-Zn volcanogenic massive sulphide mine (Pollock et al. 1972, Urabe and Scott 1983), located at South Bay of Confederation Lake and interpreted as being within a rifted back-arc or intra-arc (sub)basin succession within the tectonized Confederation assemblage (Hollings 1998; Rogers et al. 1999, 2000; see also interpretation of the "sector graben" of Thurston 1985). Given the now widely appreciated importance of extensional basinal settings (Cathles et al. 1983; Wyman 1996; Lentz 1998) and the role of chemical replacement rather than exhalative deposits (Ohmoto 1996) in the creation of many economic volcanogenic massive sulphide deposits, the search for extensional basins (or subbasins) may be more of a key factor than the search for a critical volcanogenic massive sulphide ore horizon (i.e., a synchronous, laterally continuous stratigraphic marker bed or horizon, perhaps consisting of a distal "key tuffite" or banded-iron formation unit and a proximal zone close to a volcanogenic massive sulphide deposit, volcanic centre, synvolcanic fault, or alteration pipe). Although basin analysis using sedimentology and physical volcanology is thus of great

potential value in resolving the location of (sub)basins in the Confederation assemblage and their internal stratigraphic architecture, poor exposure and a largely unknown degree of structural complexity unfortunately limit the degree of stratigraphic resolution possible. (This is a situation common to most northern Ontario greenstone belts: Devaney 1999c.)

Regarding the search for mesothermal lode gold deposits (e.g., structurally controlled auriferous quartz or quartz-carbonate veins), gold occurrences which are probably of this type are abundant in the Birch–Uchi greenstone belt (Parker and Atkinson 1992) and, according to the standard models for this type of deposit (Card et al. 1989; Thurston and Chivers 1990; Hodgson 1993; Poulsen et al. 2000; *see also* Groves et al. (1998) and Sillitoe and Thompson (1998) regarding orogenic gold deposits), these gold occurrences should be both spatially and genetically related to the late orogenic deformation zones in the belt: for example, strike-slip faults and related complex faults or shear zones that formed during a late orogenic wrenching stage (Stott and Corfu 1991; Devaney 1999a,b,d). Wrench faulting is used in a general sense (e.g., Stott and Corfu 1991; p.226; Devaney 1999d), as opposed to more specialized uses of the term (e.g., distributed shear during wrenching, versus strain-partitioned deformation during strike-slip faulting: Miller 1998, Figure 2).

As outlined elsewhere (Devaney 1999a,b, 2001, and herein), most of the conglomeratic units of the Birch–Uchi greenstone belt are interpreted as late orogenic, deformed strike-slip (pull-apart) basins, commonly known in Ontario as Timiskaming-type basins (Thurston and Chivers 1990; Williams et al. 1992, Mueller and Corcoran 1998), an interpretation which provides both the local and regional context for associated mesothermal gold deposits. Even if deformation zones are not exposed, or are poorly exposed, recognition of probable strike-slip basins implies the presence of major strike-slip fault systems bounding the conglomeratic units and/or basins. Furthermore, recent syntheses of strike-slip tectonics and late orogenic wrenching stages (e.g., Sylvester 1988; Nilsen and Sylvester 1995; Devaney 1999d) imply that the following other processes likely accompanied strike-slip faulting and related clastic basin formation and are all broadly interrelated:

1. development of local transpressional zones (Tikoff and Greene 1997; Dewey et al. 1998), including pop-up or positive flower structures (Sylvester 1988);
2. dip- to oblique-slip motions (e.g., high-angle reverse faults, and vein flats produced by vertical extension (Sibson et al. 1988));
3. development of local transtensional zones, which may include sites for pluton and dike intrusion at depth and pull-apart basins and volcanic centres at the (paleo-)surface (D'Lemos et al. 1992);
4. fault (or, at depth, shear zone) reactivation;
5. motion of large (subprovince scale) crustal blocks and indenters; and
6. relative motions of small (kilometres to tens of kilometres) intraorogenic blocks, flakes and schollen (Dewey and Sengor 1979) which form a three-dimensional network of structural domains likely to have been complexly and episodically deformed (e.g., such block domains may have undergone stages of rotation, translation, downdropping, uplift, and fragmentation).

Along with recognizing that many strike-slip faults flatten listrically at depth into detachment surfaces (Sylvester 1988; Devaney 1999d) which may underlie the blocks described in 6 above, the set of factors listed above provide a more complete, and contemporary view of the model, or scenario for Timiskaming-type sequences and related gold mineralization.Other models relevant to gold mineralization in the Birch–Uchi greenstone belt are the alkalic-type epithermal model (Richards 1995), applied to the Springpole gold-fluorite deposit by Barron (1996), and perhaps also the new intrusion-related vein gold systems model (Sillitoe and Thompson 1998; Lang et al. 2000), which may help to account for the presence of tellurides and other accessory minerals in the quartz veins at some of the area's gold occurrences.

Clastic Sedimentological and Physical Volcanological Descriptions and Interpretations of Selected Stratigraphic Units

Following the synthesis of data collected during the 1999 examination of shoreline exposures (and a few inland outcrops) shown on the maps of Pryslak (1970a,b, 1971, 1972), Thurston et al. (1974, 1981), Johns (1979b) and Thurston (1984), summary descriptions and brief interpretations of nine separate selected stratigraphic units are presented below for areas listed in a generally east to west order; for localities, refer to Figure 3 and the cited references. Most of the studied units are volcaniclastic parts of the Confederation assemblage (deep water deposits of volcanic-sedimentary, arc-related basinal settings) or younger synorogenic conglomeratic units, and are steeply dipping, variably deformed, and metamorphosed to greenschist facies (prefix "meta" omitted herein). (The term "volcaniclastic" is used in the sense of Smith and Landis (1995) and Devaney (2001). The term "deep water deposits" is used in a sedimentological sense; for example, no sedimentary structures or facies suites indicative of deposition above wave base.) Top indications are summarized in Tables 1 and 2. Whether the various deformed conglomeratic units of the Birch–Uchi greenstone belt represent late arc, Confederation age deposits or synorogenic, post-Confederation age deposits is a matter of interpretation and ongoing investigation.

EASTERN NARROW LAKE AREA

At the most eastern bay of Narrow Lake (Pryslak 1972, Thurston 1984), two facies suites are present. The eastern facies suite consists of clast-supported conglomerate (intermediate-felsic clasts; some better sorted, fine pebble beds are notable), coarse sandstone (some is quartz-rich), and minor laminated finer sandstone to siltstone, with top indications (grading, scours, load structures) to the east to northeast. Along with the absence of shallow marine or nonmarine features, the graded bedding and other features present suggest a resedimented (turbiditic) facies suite. Adjacent to the west, a facies suite of similar conglomerate (or lapillistone), sandstone, and rusty (pyritic) wacke siltstone along strike from an iron formation unit (to the south) may record more volcanic influences. These eastern and western facies suites are part (the east margin of) the "Narrow Lake assemblage" proposed by Rogers et al. (2000). At south-central Narrow Lake, a long shoreline outcrop of supposed "marble" (Thurston 1984) consists of pillowed mafic volcanic rock, with minor carbonate in some interpillow interstices. According to P.C. Thurston (personal communication, 2000), a 1 m thick marble layer is present (at low water level). Its origin is not reliably known (e.g., does the layer represent an altered horizon, or a carbonate-cemented sandstone or tuff bed, or a metamorphosed limestone bed?).

WOMAN LAKE AREA

Woman Lake is an important area, serving as the type locality for the Woman assemblage (Stott and Corfu 1991) and known for its examples of uncommon and well preserved Archean rock types (fiamme-bearing tuff, marble: Thurston 1980, 1985; Hofmann et al. 1985). The area has been the focus of recent structural studies (Fyon and Lane 1985; van Staal 1998; Crews 1999; Crews et al. 1999; Borowik et al. 1999; Rogers et al. 1999), and the locations of assemblage boundaries are being revised (Rogers et al. 2000).

Within a 7 km long array of outcrops scattered along the east shore of central and northern Woman Lake (Pryslak 1970b, 1972; Thurston 1984), exposures of conglomerate and coarse sandstone alternate

with areas composed predominantly of finer grained wacke-siltstone, and are herein treated as separate coarser and finer map units. Some workers have grouped these lithofacies together, treating all of the local clastic metasedimentary rocks as one north-trending homogeneous unit, but the uncertainties inherent in this approach may lead to interpretative errors. This is because separate sedimentary units may superficially resemble each other, but their detailed facies characteristics can record different paleoenvironments, tectonic stages, and depositional ages. For one sampled clastic rock (wacke) from this area, the ca. 2742–2732 Ma age obtained from detrital zircon grains indicates that it is of Confederation assemblage age or younger (Rogers et al. 2000).

Conglomeratic Facies

Clast-supported, crudely to well bedded polymict conglomerate (Photo 1) is interbedded with thin units (up to 1 m thick) of coarse-grained sandstone. Clast size varies greatly, both within and between outcrops, with some pebbly beds, other cobble-bearing beds, and bouldery beds (*see* Photo 1). The largest clasts are rarely as large as approximately 1 m by 0.5 m. Many of the (deformed) larger clasts are well rounded, whereas the smallest clasts are commonly more angular. Clast composition is predominantly intermediate-felsic volcanic, with accessory feldspar porphyry clasts, and ranges locally from nearly oligomict to more polymict, reflecting provenance changes. Some felsic clasts may actually be leucocratic and/or altered mafic-intermediate clasts. Quartz grains are visible in some felsic volcanic clasts. Large, coarsely vesicular olive-green clasts are distinctive in some outcrops. Small mudstone intraclasts record erosional reworking of muddy layers. The sandstone interbeds are massive and plane laminated, with rare cross-bedding and cross-laminae.

The conglomeratic facies appear to be gravelly and sandy proximal fluvial (braided river, and perhaps also alluvial fan) deposits comparable with those documented from elsewhere (e.g., Miall 1978; Eriksson 1978; Boothroyd and Nummedal 1978; Hein 1984; Mader 1985; Ojakangas 1985; Mueller and Corcoran 1998; Devaney 2000, 2001). Rogers et al. (1999, p. 194) claimed to have recognized "beach deposits" in these rocks, but using standard sedimentological criteria (e.g., Nemec and Steel 1984; Bourgeois and Leithold 1984), no beach deposits were recognized during the present study.

Top indications in these conglomerate-sandstone exposures, based on identification of sedimentologically subtle features (cross-bedding, a microripple, graded laminae, and metres-thick fluvial fining-upward sequences; for example, Photo 2), are to the west. The fining-upward sequences are defined by orderly progressions of bed coarseness, particularly in the uppermost parts of the sequences: for example, 1) coarse conglomerate, 2) fine conglomerate, 3) coarse-grained sandstone, 4) fine-grained sandstone; 1) conglomerate, 2) pebbly sandstone, 3) pebble-free sandstone, 4) silty laminae in sandstone. In contrast, Crews (1999, Figure 12) reported numerous top indications to the east for the same outcrops (based on his identifications of apparent "normal grading" in conglomerate: F.W. Schwerdtner, personal communication, 1999). Because grading in conglomerates is commonly ambiguous as a way up indicator (conglomerate beds or sets of beds may either coarsen or fine upward: e.g., Lowe 1982, Nemec and Steel 1984; Hein 1984; Middleton and Trujillo 1984; Surlyk 1984; Clifton 1984; Bluck 1986), and orderly fining-upward sequences such as those described above were not noted by Crews (1999), such tops to the east are considered herein to be incorrect. Although most top indications for other Woman Lake area rocks are to the east (van Staal 1998), the west-topping beds in the conglomeratic facies are newly identified and their presence has not been considered in previous structural analyses of the area.

Some conglomerate exposures at northwest Woman Lake (Pryslak 1972) contain significant amounts of felsic porphyry clasts and feldspathic (arkosic) sandstone, a different composition from that of the conglomerate and sandstone exposures along the east shore of Woman Lake. Whether the porphyritic and feldspathic composition of the northwest exposures signifies that they are part of a separate conglomeratic map unit, or alternatively, are a different compositional facies within the same (geographically and

structurally continuous) conglomeratic unit, is presently uncertain. This calls into question the reliability of the correlation of the local conglomeratic and wacke-siltstone units in the form of one continuous S-folded unit by some previous workers (e.g., van Staal 1998; Figure 2; Crews et al. 1999, Figure 3).

Clastic rocks at a third area, Shanty Bay (Pryslak 1970b), appear to be unrelated to the conglomerate-sandstone exposures described above. Thinly bedded fine pebble conglomerate (matrix- to clast-supported; notable jasper pebbles) and sandstone resembling the adjacent intermediate tuff outcrops are likely subaqueous resedimented volcaniclastic deposits, based on the presence of: 1) thinly layered, low energy deposits; 2) some matrix-supported mass flow deposits; 3) a probably distal population of small clasts; 4) a strong contrast with the epiclastic fluvial and resedimented facies seen elsewhere in the belt; and 5) similarities with volcaniclastic facies seen elsewhere in the belt (Devaney 2001).

Wacke-siltstone Facies

Thinly bedded to laminated fine-grained sandstone (wacke) and siltstone contain common graded beds and minor amounts of interbedded coarser pebbly sandstone and fine pebble conglomerate. Clast compositions (intermediate-felsic volcanic and porphyry pebbles) are similar to those of the local coarse (fluvial) conglomeratic outcrop areas (see above). The wacke-siltstone beds are interpreted as a subaqueous facies suite with common sandy turbidites and uncommon coarser sediment gravity flow deposits. Specific examples of coarser gravity flow (mass flow) deposits include one thick bed with a notably loosely clast-supported fabric (a disorganized bed, versus the usual tightly clast-supported fabric), and another thick bed (outcrop) with anomalously large (outsize) clasts, intraclasts, and a lack of any obvious stratification, which collectively suggest an origin via slumping. No evidence that sedimentation was synchronous with volcanism was recognized, in contrast with the interpretation of tuff interbeds and synvolcanic sedimentation by van Staal (1998, p.111).

Exposures with thin interbeds of conglomerate and graded wacke-siltstone beds, a low conglomerate to sandstone ratio, and small average clast size indicate a distal subaqueous setting compared to the local coarse (fluvial) conglomerate. Within one large and unusual outcrop, part consists of coarse, apparently fluvial conglomerate and sandstone topping to the west, in contrast with the rest of the outcrop in which a variety of bed types (fine pebble conglomerate, pebbly coarse-grained sandstone, and thinly bedded fine-grained sandstone with graded laminae, in units up to 1 m thick) top to the east. This outcrop may record a local facies change (e.g., an originally rapid or abrupt transition from fluvial to resedimented fan-delta slope facies) which has been folded. However, in the absence of well constrained depositional ages for the fluvial and subaqueous facies suites, and given the potential for unrecognized stratigraphic and structural complexities (incomplete exposure limits resolution), such simplistic, proximal fluvial to distal subaqueous correlations are suspect. (As an example of such complex and suspect correlations, clastic units in the Rainy Lake area previously considered to be synchronous deposits have been described by Fralick and Davis (1999) as older turbiditic Coutchiching sandstones and younger, postfolding event, Seine fluvial conglomerates.)

At some sites, the thinly bedded wacke-siltstone has been highly deformed into lensoid and sigmoid shapes (sheared and transposed layers), with tight folding producing common reversals in top directions (i.e., to both east and west) within small outcrops. Within the wacke-siltstone exposures as a whole, top indications are to both the west (overturned beds) and east, in contrast with the prevalent tops to the west identified in the conglomeratic facies (Table 1).

Small igneous intrusions (e.g., quartz porphyry dike, folded mafic dikes) are present in some outcrops of the wacke-siltstone facies but were not observed in any of the coarse fluvial conglomeratic exposures, implying that either: a) there are facies suites of two different ages present (i.e., predikes subaqueous wacke-siltstone versus postdikes fluvial coarse conglomerate), or b) the dikes more easily

intruded the wacke-siltstone than the potentially correlative (synchronous) and more proximal fluvial conglomeratic section.

Given the discussion above, the tectono-stratigraphic setting(s) of the conglomeratic and wacke-siltstone units is uncertain. Potential settings include a late arc subbasin (cf. Hathway 1993), a postarc synorogenic strike-slip basin, or perhaps another type of fault-bounded basin. In contrast, many other conglomeratic units in the Birch–Uchi greenstone belt recently have been interpreted as postarc synorogenic pull-apart basins (Devaney 1999a,b, 2001); see sections on Sundown Lake Area and Cromarty Lake Area, below.

Intermediate Volcaniclastic Unit

On a small lake east of the south end of the eastern Woman Lake conglomeratic exposures, a large, previously unmapped shoreline outcrop contains tuff-breccia (clast-supported), lapillistone, lapilli-tuff, tuff (laminated to thinly bedded), and autoclastic flow breccia. Clasts are oligomict (intermediate volcanic composition only), with angular and polygonal (polyhedral) shapes common (e.g., suggestive of clasts sourced locally from jointed lava flows). A rare rubbly subfacies (variably matrix-supported, with blocks up to 1 m, and odd ameboid or pillow-like clasts tens of centimetres in diameter) may represent autoclastic lava flow breccia deposits.

These volcaniclastic rocks are likely part of an older unit that is unrelated to the conglomeratic units described above.

Marble

At Woman Lake narrows, a well layered marble unit (Thurston 1984; Hofmann et al. 1985) has been tectonically deformed to a high degree. Although the thin beds and laminae present are thought to reflect the presence of originally thin strata, small-scale (less than 1 m amplitude) tight folding and transposition of layering, commonly via slip along a cleavage approximately perpendicular to bedding, are characteristic of the marble unit. Dome-like stromatolitic features appear to be tectonically folded laminae and beds rather than primary sedimentological features; further detailed structural analysis is suggested.

SOUTHWEST ARM OF CONFEDERATION LAKE AREA

Volcaniclastic strata (tuff, lapilli-tuff, lapillistone) near the Knott-Mitchell Township line were previously mapped inconsistently; the same outcrops were described as "epiclastic volcanic conglomerate" (Pryslak 1970a) and intermediate "tuff and lapilli-tuff" (Pryslak 1971). The outcrops displays little or no evidence of sedimentary reworking, so the latter volcanic terminology may be more appropriate.

In a nearby area of predominantly volcanic rocks with iron-copper-zinc sulphide mineralization, located about 1 km north of Confederation Lake (property locality 7 of Pryslak 1971): 1) an outcrop containing magnetite iron formation, a lithology previously not described from this area, was found (the presence of such an exhalite facies enhances the volcanogenic context of the local sulphide mineralization); 2) Pryslak (1970a) noted exposures of granitic boulder conglomerate, but no such rocks were found during the present study (some exposures of tectonized hybrid mafic-felsic rocks were tentatively identified near the margin of the belt (also the margin of a granitic body), and may represent the conglomerate exposures), and the rock types noted on the map of Pryslak (1971) are likely more

correct; and 3) no outcrops of marble, a lithology noted in this area on the map of Thurston (1984), were identified during the present study; it is more likely that carbonate alteration is present (Pryslak 1971).

SOUTH BAY AREA OF CONFEDERATION LAKE

A north-northeast-trending map unit of various felsic volcanic lithofacies and quartz-feldspar "porphyry" is exposed in eastern Mitchell Township and adjacent townships (Pryslak 1970a,b, Thurston et al. 1974; Thurston 1984). Many of the rocks in this map unit have been variably and complexly altered and deformed, particularly in southeast Mitchell Township (Fly Lake area).

The former South Bay mine, a 1.6 Mt copper-zinc volcanogenic massive sulphide deposit (Pollock et al. 1972, Urabe and Scott 1983) is located at South Bay of Confederation Lake. The quartz-feldspar porphyry in the vicinity of the South Bay mine is of particular interest; these rocks were originally mapped as intrusive (Pryslak 1970b), but well defined fragmental (pyroclastic) textures are locally present (Pollock et al. 1972, Dykes 1979; N. Rogers and P.C. Thurston, personal communications, 1999). Such textures observed during the present study include:

1. locally abundant broken feldspar grains (including triangular and highly angular outlines);
2. some rounded grains and lapilli (feldspar and rare small lithoclasts; the rounded grains are not to be confused with resorbed quartz grains that crystallized as round grains; the accessory lapilli, of fine-grained and/or aphanitic felsic volcanic and feldspar porphyry composition, superficially resemble xenoliths);
3. centimetre-scale clustering of grains (a poorly sorted texture, different from the appearance typical of an intrusive crystalline bimodal texture with more evenly spaced phenocrysts); and
4. variable grain-supported to matrix-supported texture.

The fragmental facies of "porphyry" are thus more correctly termed coarse crystal tuff or lapilli-tuff (Photo 3). However, it is a problem (of field mapping) that in a typical outcrop, only a small part (1%?) of the exposure surface reveals the clastic nature of the rock. Elsewhere, farther from the minesite, some of the porphyry is intrusive (good local evidence of dikes and sills), and some outcrop surfaces offer only poor and equivocal data regarding intrusive versus extrusive origins.

Other volcanic facies at the minesite include spherulitic rhyolite lava flows, with distinctive black fresh surfaces and white weathered surfaces. The spherules (devitrification nodules in formerly glassy flows) are centimetre-scale ovoids in cross-section and are prolate in three-dimensional views. Variations in the amount (concentration) or size of spherules defines flow layers up to tens of centimetres thick.

Alteration (e.g., chlorite, sericite) and tectonic deformation (e.g., narrow shear zones, folded and transposed quartz veins, east-plunging lineation) have obscured or obliterated many primary fabrics. In one outcrop displaying a locally rare example of well defined pyroclastic fabric, lapilli lithoclasts and distinctly smaller, more flattened pumiceous lapilli are set in a fine-grained tuff matrix. At a larger scale, rare sites display a stratigraphy of units each several metres or more thick (e.g., 4 units observed in one 60 m outcrop cross-section), similar to the known subsurface stratigraphy (e.g., Stott and Corfu 1991; Figure 6.26a).

South of the porphyry exposures at the former minesite, for up to several kilometres along strike, Pryslak's (1970a,b) maps show many felsic tuff to lapilli-tuff outcrops. These fragmental facies are mostly massive (unbedded or poorly bedded in small outcrop views; views of coarse versus fine tuff beds tens of centimetres thick are rare) and monotonous, with common sericitic (yellow, highly schistose) and rusty pyritic zones and rare pumiceous clasts (highly flattened and more altered relative to other lapilli).

Lapillistone and clast-supported tuff-breccia are locally common in units cropping out 1 to 2 km east of the minesite.

At some of the supposed "tuff" outcrops south of the minesite, the present study identified exposures of felsic (rhyolitic) lava flow facies with well preserved flow banding (synvolcanic rheomorphic folds, with local brecciation) and spherulitic (devitrification nodule) textures (Photos 4, 5). Flow banding is defined at multiple scales (millimetre, centimetre, metre) via spherule size and concentration, fine lamination, and synvolcanic folding (with local small-scale auto-diking between broken flow layers). Autoclastic flow breccia fabrics are defined by rubbly layers, clasts with angular and shard-like shapes (plus some rounded clasts, presumably from local abrasion), and some jigsaw-clast (crackle-breccia) fabric, including subcentimetre scale examples. The various features and fabrics present compare well with textbook examples of glassy lava flow facies (e.g., McPhie et al. 1993).

Small outcrops of tuff on the east shore of South Bay, about 1.0 km south of and along strike from the former minesite, contain both small (centimetres) dark schistose fragments that appear to be mudstone intraclasts (Photo 6) and irregularly shaped black bands, patches and anastamosing lenses centimetres wide. The dark mudstone bodies likely represent remnants of sheared mudstone beds (via either soft-sediment slumping, or hard-rock transposition of layering?). Stratigraphic units and fragments of mudstone (argillite) are present in the South Bay ore deposit (Pollock et al. 1972; Stott and Corfu 1991; Figure 6.26), and if the exposures with the small mudstone fragments and bands are correlative, they represent a newly identified distal facies of the ore horizon.

South Bay Unit: Altered Rocks Correlative With South Bay Area Volcanic Facies

Intensely altered and deformed rocks are common in southeast Mitchell Township (west of Fly Lake), south of, and along strike from, the correlative rocks with the well preserved features described above. Pyroclastic (or volcaniclastic) facies are identifiable in horizons where alteration and deformation are less severe. A footwall-type assemblage of minerals is present (chlorite, sericite, garnet, disseminated sulphides: Pryslak 1970a); for example, chloritic schists with coarse sand/tuff size quartz grains are interpreted to signify (metamorphosed) synvolcanic mafic alteration (via Fe- and Mg-rich fluids) of felsic tuff. Distinguishing between true clasts (including some likely pumiceous ones) and false clastic texture during field examination of outcrop surfaces of the variably altered rocks was frequently a difficult and uncertain exercise. The local ovoid pseudo-clasts centimetres in size defining false clastic texture are products of factors such as:

1. the patchy distribution of alteration minerals; and/or
2. an anastamosing pattern of schistosity surfaces (an augen-like fabric); and/or
3. shearing and transposition of thin alteration layers; and/or
4. weathering along fractures and other surfaces.

(For illustrated reviews of alteration-produced pseudo-clasts and pseudo-matrix, see Allen (1988) and McPhie et al. (1993).) Mapping the stratigraphic distribution and form of the alteration units was beyond the scope of the present study.

Based largely on data from diamond drillholes, Noranda Inc. (Smith 1999) has reported numerous examples of significant volcanogenic massive sulphide-type alteration and Cu-Zn sulphide mineralization zones in the volcanic units forming the southwest extension of the Birch–Uchi greenstone belt. These mineralized zones, with some notably high Zn values (e.g., 6–31% Zn over a few metres of drill core:

Smith 1999, Table 1), are scattered over a 50 km distance along regional strike southwest of the South Bay mine (Smith 1999, Figure 2), an area of poorly constrained stratigraphy and structure. Similar alteration and Cu-Zn mineralization in Confederation assemblage strata are found farther to the west in the stratigraphically contiguous Red Lake belt (Parker 1999b).

LOST BAY AREA OF CONFEDERATION LAKE

Volcaniclastic facies in the Lost Bay area were previously mapped and interpreted by Thurston et al. (1974), Thurston (1985), Stix and Gorton (1991), and Rogers et al. (1999). The very common graded beds suggest a deep water turbiditic succession, but as in other similar volcaniclastic units, distinguishing between subaqueous pyroclastic and resedimented deposits is problematic (Stix and Gorton 1991; Cas and Wright 1991; Devaney 1999c). At Lost Bay, because primary features in the rocks are generally well preserved (i.e., little penetrative deformation) and top indications to the west are ubiquitous, the rocks have been treated as a continuous, quasi-homoclinal stratigraphic section by most workers and formations have been named (e.g., Thurston 1985; Stix and Gorton 1991; Rogers et al. 1999; N. Rogers, personal communication, 1999). Stix and Gorton (1991) noted a local provenance change, with more abundant porphyry clasts present in the conglomerate (or lapillistone) in the western, upper part of the section.

Within the beds of clast-supported conglomerate/lapillistone (Photo 7), largely composed of felsic volcanic and porphyry pebbles: 1) the clasts are typically small (few centimetres), suggesting deposition in a medial setting between coarser, more proximal gravels (or tuff-breccias) and a finer, sand-dominated distal zone; 2) the clast frameworks are commonly fairly well sorted, suggesting that much of the gravel was winnowed from a coarser population of clasts nearer to the source area; and 3) rounded clasts are common (and in some exposures, angular clasts are equally common; e.g., Photo 7), suggesting a significantly long history of transport and abrasion for the rounded clasts. The less abraded angular clasts are interpreted as being more source-proximal, including polyhedral clasts likely eroded from jointed volcanic rocks, but may also include clasts broken during transport.

Within the beds of laminated to thinly bedded (centimetres thick) sandstone and siltstone (or tuff), well developed normal grading is very common and inverse grading is rare. (Correct identification of inverse grading is important to structural analysis; assuming that all grading present is normal (i.e., fining-upward) may lead to the incorrect interpretation of folding in a homoclinal succession. Inverse grading is best identified where other types of corroborating, less equivocal top indications are present nearby, ideally within the *same* bed.) Uncommon small (<10 cm) asymmetric soft-sediment folds and rare cross-laminae (ripples; Photo 8) suggest that the basin was more distal approximately to the north, but with so little basin analysis data available, caution is required.

Ideally, pyroclastic deposits should record evidence of hot emplacement and directly volcanic deposition with no resedimentation (Cas and Wright 1991). As noted by Stix and Gorton (1991) and confirmed by the present study, such evidence is not present at Lost Bay, and consequently there is little support for Thurston's (1985; Figure 7) interpretation of seven ignimbrite units in this area. Thus, for most of the Lost Bay rocks mapped as felsic lapillistone, lapilli-tuff and tuff, sedimentary terminology is likely more appropriate: for example, volcanic pebble clast-supported conglomerate, pebbly sandstone, sandstone and siltstone, respectively. However, given the sporadic presence, particularly in western (upper) parts of the succession, of volcanic features such as:

1. well defined pumiceous clasts, including rare beds composed of large pumice clasts;
2. newly identified lava flow facies with flow banded, autobrecciated, spherulitic fabrics; and
3. rare interbeds of exhalative facies of chert and magnetite iron formation,

at least some of the sedimentation was synvolcanic, and the Lost Bay succession may represent a complex mixture of sedimentary (cold, nonvolcanic, epiclastic), volcaniclastic (cold, reworked volcanic material), and minor pyroclastic (hot, directly volcanic) facies.

Comments on Rift Basin Analysis

N. Rogers (personal communication, 1999; and Rogers et al. 2000) has suggested that the succession at Lost Bay represents the fill of an intra-arc rift basin. It is notable that there is presently no evidence regarding the margins of such an hypothesized basin (e.g., faulted or unconformable margins?), but unfortunately this situation is typical of efforts to perform sedimentary basin analysis of units within Archean greenstone belts in the generally poorly exposed (forest- and lake-covered) terrain of northern Ontario (Devaney 1999c); critical horizons such as major faults tend to lie beneath covered intervals. Although speculative, Rogers' rift basin interpretation is reasonable and in accord with the regional geology of the Confederation assemblage, particularly the likely presence of a former extensional basin (or subbasin) to the west, in the vicinity of the South Bay ore deposit (i.e., a deep water rifted arc basin as the setting for this Kuroko-type sulphide deposit). However, given the equivocal nature of the deep water sedimentary facies present (nondiagnostic of any specific tectonic setting) and the lack of information on basin margins, synsedimentary faults, and synorogenic faults (including potential reactivation of earlier faults), other scenarios and basinal settings should also be seriously considered for the Lost Bay succession.

UCHI LAKE AREA

For shoreline exposures along Uchi Lake, a variety of wacke and intermediate to felsic tuffaceous units were previously mapped by Thurston et al. (1974) and Thurston (1984). In general, numerous thin units of wacke and felsic volcaniclastic facies crop out along the southeast side of the northeast-trending lake, in contrast with more monotonous intermediate volcaniclastic facies exposed along parts of the northwest shore of the lake. As in other units of the Confederation assemblage within the belt, a wide range of volcaniclastic lithologies are present (tuff-breccia and lapillistone, or conglomerate; lapilli-tuff, or pebbly sandstone; tuff, or coarse- to fine-grained wacke; fine tuff, or siltstone, some of which is laminated), and as discussed below, an assessment as volcanic or sedimentary is commonly uncertain. Strata vary from little deformed, with good preservation of primary features, to intensely deformed (e.g., Photo 9); numerous strike-parallel deformation zones are likely present in the commonly thinly layered succession. Graded beds and other top indications are mostly to the northwest (Tables 1, 2); as in some other greenstone belts, an asymmetric folding style (e.g., S-folds with a preferential cropping out of northwest-younging strata comprising the longer fold limbs, versus few exposures of southeast-younging strata of the shorter fold limbs) may account for the preferred top direction in the complexly tectonized succession.

Highlights of the local facies details are:

1. between Wabunk Bay and the main (central) part of Uchi Lake, locally distinctive hornblende phenocrysts in some clasts define a north-trending correlatable stratigraphic horizon;
2. in the same area, one outcrop displays well defined pumiceous lapilli-tuff to tuff-breccia; the oligomict pumice clasts are highly vesicular (bubbly-looking, with variably deformed vesicles) and oddly shaped (probably broken clasts?), and form poorly sorted pyroclastic beds (one 72 by 31 cm mega-clast observed); and
3. at the east end of an east-trending bay of central Uchi Lake, located about 1 km west-southwest of the north end of Leg Lake, a small outcrop displays superb and rare examples of penecontemporaneous

(soft-sediment) deformation fabrics (Photos 10 and 11; compare with the hard-rock deformation fabric in Photo 9); deformation of sediments in this outcrop before lithification is recorded by cross-sectional views of the following 0.01-0.1 m scale features: a) jigsaw-clast breccia fabric with sedimentary matrix (cohesive, compacted sediment affected by shock); b) ovoid shapes, a product of loading or other types of folding (e.g., via noncylindrical folds with bed-parallel axial planes, like sheath folds seen in cross-section); c) dikes and sills (injection of a more fluidized matrix sediment between pieces or zones of more competent and cohesive beds); d) a slump plane truncating penecontemporaneously folded strata; e) load and flame structures; and f) matrix-rich intraclastic breccia (probably a slump deposit representative of a more evolved state of disaggregation than the incipient brecciation of a and c above).

Comments on Equivocal Volcaniclastic Facies (Tuff-wackes) and Very Thick Beds

Strata in the Uchi Lake area are problematic in that, based on this study's observations of outcrop surfaces, there appears to be little or no descriptive difference between outcrops mapped as felsic tuff versus those mapped as wacke by Thurston et al. (1974). Graded beds, with top indications mostly to the northwest, are present in some of the "tuff" and "wacke" exposures. As in many similar units in other greenstone belts, the frequently questionable identification of "tuffs" versus "wackes" is likely partly a result of a mapping bias produced by the normally small (<1–10 m) size of exposures; in the past, thinly bedded facies tend to have been labeled as wacke, whereas thickly bedded, poorly bedded or "nonbedded" facies (outcrops of "nonbedded" tuffaceous and/or sandy facies are probably part of very thick beds) tend to have been labeled as "tuff" or "lapilli-tuff." The supposed "tuffs" and "wackes" may be merely minor, local variations in lithofacies within a single deep water turbiditic succession.

The tuff-wacke problem has been a long-standing one in Archean geology, and solving it would require a reliable view of the stratigraphic context of the units and subunits involved: for example, an identifiable regional stratigraphic and/or basinal pattern of proximal tuffs near a volcanic centre, a medial zone of volcaniclastic material variably reworked by sedimentary processes, and a distal sedimentary zone of wacke and other sedimentary facies (see Devaney 1999c and Devaney 2001, Table 1). Such volcanic to sedimentary intrabasinal gradients (lateral facies changes) have been documented from some well exposed successions (e.g., Busby-Spera 1985, 1986, 1988; Easton and Johns 1986; Houghton and Landis 1989; McPhie et al. 1993; Smith and Landis 1995). Unfortunately, such stratigraphic context is usually not available or reliable in the tectonized, discontinuously and poorly exposed map units (of deformed stratigraphic cross-sections) that are found in the Archean greenstone belts of northern Ontario. Also, the gradational nature of some proximal to distal facies changes may not be conducive to geologists' efforts to make arbitrary and convenient tuff versus wacke distinctions.

Thick beds, particularly those thicker than the 1–10 m width of many of the continuously exposed outcrop surfaces available in much of northern Ontario, may be common in nondistal volcaniclastic units and/or deposits. In proximal to medial settings near volcanoes, given the abundance of unconsolidated coarse (pyro-)clastic material and the high probability of frequent slumps and sediment gravity flows (because of earthquakes and high depositional slope angles; Figure 4), thick sediment gravity flow deposits (e.g., 5–100 m thick beds) would be expected, and the fact that such very thick beds are so rarely identified or interpreted is likely a result of exposure (field mapping) bias rather than the apparent absence of very thick beds (Devaney 1999c).

SUNDOWN LAKE AREA: CONGLOMERATIC PULL-APART BASIN INTERPRETATION

At Sundown Lake (Johns 1979a,b), clast-supported polymict conglomerate and interbedded sandstone (cross-bedded, cross-laminated, plane laminated) form a 4 km long north-trending map unit. Newly identified top indications to the west are numerous and of good quality in this unit (e.g., Photos 12, 13, 14). Both fluvial and resedimented (turbiditic) deposits appear to be present, and these clastic facies are very similar to the conglomeratic units exposed 10–30 km to the northeast, in the Birch Lake area, which have been interpreted as the infill of late orogenic pull-apart basins (Devaney 1997, 1998, 1999a,b, 2001).

The main conglomeratic facies suite present has the following characteristics. The conglomerate beds have tightly clast-supported frameworks. Clasts are mostly of felsic composition, with various volcanic and porphyritic textures. Granitic clasts and recessively weathered garnetiferous mafic clasts are locally notable. Most of the clasts (i.e., extrabasinal lithoclasts) are well rounded (with one outcrop displaying an unusual example of three-dimensionally exposed well rounded shapes), versus the very angular shape of some muddy intraclasts. Within conglomeratic horizons, bedding is crudely to well defined by laterally consistent variations in clast size (e.g., fine pebble (<2 cm clasts) beds versus cobble-bearing beds), with such beds parallel to nearby sandstone interbeds. Some outcrops display a lateral tapering of beds (e.g., over 0.5 to 2 m along strike). Compositional bedding is uncommonly present, in which clusters of clasts of identical composition are parts of distinct beds. Conglomerate beds are up to tens of centimetres thick, but there is a recognition bias towards thin beds in the characteristically small outcrops. Sandstone lenses are typically thin (10 cm) and sharply defined, and comprise either single beds or stacked thin beds. Observed internal structures consist of coarse-grained trough cross-sets, fine-grained cross-laminae (trough ripples) and plane laminae, concave-up scour surfaces, and pebble bands (*see* Photo 12).

The sedimentary structures, textures and stratification style of much of this conglomeratic unit are typical of gravelly braided river deposits (Miall 1978; Eriksson 1978; Boothroyd and Nummedal 1978; Hein 1984; Mader 1985; Mueller and Corcoran 1998): for example,

1. the intermittent traction (rolling forward) of clasts over gravelly bar surfaces and channel floors, with eventual aggradation (vertical accumulation) of clasts, produced the clast-supported frameworks;
2. abrasion during such tractional transport rounded many of the clasts;
3. local variations in flow power, clast size sorting (e.g., downstream fining on bar surfaces), and the size of clasts supplied to river reaches produce beds of variable mean clast size and sorting;
4. tapering beds reflect the infilling of small-scale braided channels (e.g., small higher-order channels on top of gravel bars, the gravel bars being separated by larger lower-order channels), or partial erosion by overlying channels and scours;
5. compositional bedding suggests either: a) a proximal setting in which the polymict (heterolithic) gravel composition was not yet thoroughly homogenized, or b) a change in the provenance and subsequent delivery of clasts;
6. the thin sandy lenses represent the low-stage infilling of higher-order channels; the upper surfaces were structured as dunes (trough cross-sets), flat beds, and ripples, with some scours and mud drapes (mud layers preserved indirectly as intraclasts); and
7. angular mudstone intraclasts signify the erosional reworking of desiccation-cracked mud layers in subaerial abandoned bar-top channels; note that the shapes of the angular intraclasts versus the rounded lithoclasts present shows that primary clast shapes are fairly well preserved in these metamorphosed deposits.

These proximal fluvial facies compare well with very similar deposits elsewhere in Superior Province (e.g., Ojakangas 1985; Mueller and Corcoran 1998; Devaney 2000, 2001).

A few small outcrops at west-central Sundown Lake contain a very different facies suite consisting of a variety of well stratified conglomerate and sandstone facies (e.g., thin beds, shallow (10 cm deep) channels, ripples and cross-beds, graded bedding (Photo 14), and fine pebble conglomerate beds that represent a finer and better sorted distal subpopulation of lithoclasts) interpreted as high-energy subaqueous resedimented deposits.

Interpretations of graded bedding can be problematic in that not all graded beds are deep water turbidity current deposits; some are shallow water storm beds (tempestites), which may contain internal layering similar to Bouma sequences (Aigner 1985), and others represent waning stage fluvial overbank flood beds (inundates of Seilacher 1991). The local subaqueous facies suite contains no unequivocal evidence of shallow marine or lacustrine wave-produced structures (e.g., wave ripples, hummocky cross-stratification; see Bourgeois and Leithold 1984), but because fluvial and resedimented facies are commonly closely juxtaposed in continuous and conformable fan-delta or braid-delta successions, the resedimented facies need not be deep water deposits. In the fan-delta or braid-delta scenario (Ethridge and Wescott 1984; McPherson et al. 1987), deposition of turbidites and other mass flows can occur on the delta front (a steep subaqueous delta slope, with the sediment supplied by rivers on the nearby subaerial part of the delta) rather than in a deep water setting. Rapid sedimentation in such a shallow water setting can bury turbidites and other mass flows at levels above wave base, protecting some of such deposits from wave reworking (Devaney 1991). Such a deltaic scenario is suggested for the fluvial and resedimented facies that comprise the Sundown Lake conglomeratic unit.

Intermediate spherulitic lava facies crop out along the east shore and northeast end of Sundown Lake, east of and adjacent to the conglomeratic unit. Importantly, some dark clasts that are common within the local polymict conglomerate beds have a knobby-weathering spherulitic texture (Photo 15) apparently identical to that of the spherulitic lava facies. The presence of these clasts would seem to record Late Archean subaerial exposure of the spherulitic rock and very local derivation of the spherulitic clasts, and implies that the east margin of the present conglomeratic unit, although likely the eroded root of the original Late Archean basin margin, preserves the same juxtaposition of rock types as the original basin margin did.

A 1.5 km long quartz-feldspar porphyry intrusion (sill?) is present along the west margin of the northernmost part of the conglomeratic unit (Johns 1979b). Similar small felsic porphyry intrusions are also present marginal to the conglomeratic units (pull-apart basins) to the northeast, at South Bay of Birch Lake and Satterly Lake (Devaney 1999b, 2001); the presence of such quartz-feldspar porphyry intrusions marginal to Archean Timiskaming-type basins is common (e.g., Mueller et al. 1991; Mueller and Corcoran 1998), and likely reflects the ascent of magmas along the faults that characteristically bound such basins.

Based on the facies interpretations and other features noted above, the fluvial and related resedimented deposits at Sundown Lake are interpreted as the deltaic infill of a strike-slip basin (or pull-apart basin; see below) very similar to units/basins to the northeast (see Devaney 1997, 1999b, 2001, and references therein). The slightly sigmoidal shape of the Sundown Lake conglomeratic unit (Johns 1979a) suggests the interpretation of a lazy-S shaped, sinistral-sense pull-apart basin, opposite to the lazy-Z shaped, dextral-sense pull-apart basins interpreted for nearby sites to the north (Devaney 1997, 1999b, 2001) and consistent with the dextral to the northeast, sinistral to the southwest form of the Birch–Uchi greenstone belt in the regional tectonic (late orogenic) model proposed by Devaney (1999a,b, 2001). The interpretation of conglomeratic units as the infill of pull-apart basins, or other types of strike-slip basins,

is of economic interest because the basin-bounding fault zones are potential sites for mesothermal lode gold deposits (Devaney 1997, 1999d).

The sporadic presence of euhedral garnet crystals in both the conglomerate matrix and mafic clasts shows that the rocks are part of the metamorphic aureole north of the Okanse Lake pluton (2702.7–2699.4 Ma old: Beakhouse et al. 1999), which requires that the clastic infill of the basin (conglomeratic unit) be older than this pluton and younger than the ca. 2740 Ma clasts of Confederation assemblage volcanic clasts it contains. Thus the ca. 2715–2720 Ma age suggested for the other pull-apart basins of the Birch–Uchi greenstone belt by Devaney (1999b, p. 59) may also be appropriate for the Sundown Lake unit.

CROMARTY LAKE AREA

Two northwest-trending facies suites (with top indications to the southwest) are present in the Cromarty Lake area, which is the eastern continuation of the Satterly Lake pull-apart basin conglomeratic unit described and interpreted by Devaney (1999b, 2001). The coarse suite consists of clast-supported polymict conglomerate with interbeds (small lenses) of coarse sandstone. Most of the clasts are of intermediate to felsic volcanic and feldspar porphyry rock types, plus a few granitic cobbles. One subtle fining- and thinning-upward sequence was recognized, with mudstone intraclasts in its upper part. The intraclasts likely represent a ghost-like facies (Mader 1985, p.43), a mud bed which formerly capped a thin fluvial sequence (e.g., low stage slack water deposits in overbank areas such as an abandoned channel or ephemeral pond; desiccation polygons formed cohesive and durable mud intraclasts) but was eroded away by the higher-energy base (river channel floor?) of the next (overlying) sequence or event, leaving only a few scattered intraclasts as a record of the mud bed.

Mafic clasts (gabbroic or mafic volcanic, and up to boulder size) are prominent along the northeast margin of this clastic map unit, as was also noted by Good (1988), and resemble the gabbroic unit adjacent to the northeast. This suggests that the gabbroic clasts were very locally derived and that, although today's peneplain exposes a deep erosional level, the original basin margin relationship of subaerially exposed gabbroic areas supplying clasts to an adjacent conglomeratic basin has been preserved in these tectonized units.

A finer suite of laminated to thinly bedded very fine-grained sandstone to siltstone, with some graded bedding, is variably kinked, folded and sheared. Coarser and thicker sandstone interbeds (up to medium and coarse sand (0.25–1.0 mm grains), in 10–15 cm thick beds) form more structurally competent members in heterogeneously layered deformed sections. Axial planes of late chevron folds form an "S_2" fabric cross-cutting the main northwest-trending schistosity. (If these fine-grained strata in the Cromarty Lake area represent the fill of a deformed pull-apart basin, episodes of deformation produced more than one cleavage in these clastic rocks.)

Rare interbeds (in two outcrops) appear to be of tuffaceous or more feldspathic composition (e.g., arkosic sandstone or feldspar crystal tuff? pebbly sandstone or lapilli-tuff with feldspar porphyry clasts?). If true tuffaceous beds are present, this need not imply that the beds would be of Confederation assemblage age. The source area for these beds could have been felsic exposures near the basin margin (e.g., erosion of quartz-feldspar porphyry stocks, or erosional removal of any related, formerly present, post-Confederation assemblage volcanic edifices?). Less equivocal exposures of notably felsic, coarse epiclastic facies are seen elsewhere in the Birch–Uchi greenstone belt, at sites which are less deformed and have a more obvious paleogeographic context (e.g., at or very near pull-apart basin margins). The best such sites are at northwest Woman Lake (arkosic sandstone, relatively abundant felsic porphyry clasts; see above), Louwag Lake (oligomict conglomerate compsed of felsic porphyry clasts), and South Bay of Birch Lake (oligomict conglomerate composed of felsic volcanic clasts: Devaney 1999b, 2001).

Archean workers often lump all metasedimentary map units together in their descriptions and interpretations of study areas, but in some cases, deformed conglomerates and adjacent map units of deformed sandstones (e.g., wackes and any related siltstone-slate facies) might represent separate map units, particularly where older wacke units may have formed the basement to pull-apart basins (as may be the case at some sites in the Birch–Uchi greenstone belt (Devaney 1999b, 2001), including Woman and Cromarty lakes). In such a case, younger conglomerates and related, more distal sandstone facies would lie unconformably above older clastic rocks, but potential older-versus-younger relationships might not be readily discernable in tectonized and poorly exposed areas, causing some workers to group different sedimentary units together. Given the potential complexities of late orogenic episodes of compression, transpression, and transtension, which may include multiple stages of deformation of pull-apart basins (Devaney 1999d), structural fabrics in younger conglomeratic basin fill may be difficult to distinguish from those in older basement strata, particularly where they are coplanar (or nearly so) owing to intense deformation and rotation of fabrics.

BERTHA LAKE AREA

The wacke unit in the Bertha Lake area (Thurston et al. 1981), with rare interbeds of magnetite banded iron formation and slate, has been highly metamorphosed (e.g., to garnetiferous biotite schist, with much transposition of bedding). This has obscured or obliterated most of the probable original sedimentary features, as was also noted for localities along strike to the west (e.g., Slate Lake Series wackes near McNaughton Lake) by Johns (1979a, p.26). Rare granitic dikes and sills trend at 120°, and as cross-cutting bodies might be worth radiometrically dating in order to bracket the timing of sedimentation (i.e., younger than any detrital zircon grains, and older than the dikes).

Discussion

Since various aspects of the regional geology of the southern Birch–Uchi greenstone belt (e.g., volcanic stratigraphy, including correlations of cryptic stratigraphic units based on geochemical composition alone; geochemistry, including geodynamic signatures defined in currently popular diagrams; geochronology; definitions of new assemblages; regional structural analysis) are the subject of other ongoing studies (e.g., Rogers et al. 2000), a detailed regional interpretation of the greenstone belt would be premature and beyond the scope of the present study, and is, therefore, not presented; however, the descriptions and interpretations of the selected volcaniclastic and epiclastic units outlined herein are relevant to certain segments of the history of deposition and mineralization in the belt, and should be incorporated into a new synthesis of the tectono-stratigraphic evolution of the belt. One aspect of this evolution which has already received attention is the interpretation of intra-arc rifting during deposition of the Confederation assemblage, based largely on geochemistry (suggested geodynamic signature) and the likely extensional (sub)basin context of the South Bay volcanogenic massive sulphide deposit (Hollings 1998; Rogers et al. 1999). Another tectono-stratigraphic hypothesis, previously outlined in detail elsewhere (Devaney 1999a,b, 2001), is the interpretation of a late orogenic indenter or promontory pattern for the arcuate map-view pattern of the belt (*see* Figure 1), with related (coeval) strike-slip basin deposits.

VOLCANICLASTIC STRATIGRAPHIC UNITS OF THE CONFEDERATION ASSEMBLAGE

The volcaniclastic facies in the four selected units and/or areas described herein are typical of Archean subaqueous volcanic successions, with some interesting new lithofacies details (e.g., for Lost

Bay, South Bay areas), but the exposures offer little specific information regarding the larger-scale internal stratigraphic architecture (geometry) of any discrete Confederation assemblage volcanic-sedimentary basins. Reliable recognition of basinal architecture and the stratigraphic gradation from pyroclastic material to volcaniclastic deposits reworked by sedimentary processes (*see* Figure 4) depend on good continuity of exposure and good stratigraphic resolution (e.g., multiple correlations within a thick stratigraphic unit, and correlation from one tectonized unit to another), both of which are normally lacking in the poorly exposed, multiply tectonized greenstone belts of northern Ontario.

In the South Bay area, imperfect exposure quality and a significant level of largely unconstrained tectonic deformation inhibit stratigraphic resolution and thus frustrate attempts to apply volcanogenic massive sulphide-relevant volcanic facies models (e.g., McPhie et al. 1993). Generally speaking, the fit of the succession to models for proximal facies of a subaqueous volcanic centre (Thurston 1985) is good, but in terms of actually documenting specific facies changes in detail (e.g., lateral facies changes, at the 0.5–5 km scale) for the purpose of predicting the locations of potential new volcanogenic massive sulphide deposits, the outcrop data are not precise enough. It is likely that three-dimensional data from drillholes would provide a better stratigraphic framework. Hollings (1998) noted significant variability in the geochemical composition of felsic volcanic rocks in the South Bay area, and suggested that this reflected the former presence of "multiple penecontemporaneous vents and magma chambers" (Hollings 1998; p.189). Such multiple closely spaced sources of pyroclastic material (e.g, less than 10 km apart?) would result in stratigraphic complexity rather than simplicity. Recognition of a caldera context for the volcanism (Thurston 1986b) would likely require a more extensive stratigraphic analysis than in the present study.

For the Lost Bay succession, the documentation of facies details herein:

1. supplements that of previous studies;
2. does not confirm some aspects of previous studies: for example, there is a predominant or significant sedimentary component, and no ignimbrites (Thurston 1985) were recognized; the succession is not completely epiclastic, as stated by Rogers et al. (1999), because there is a significant synvolcanic component too; and
3. generally confirms the work of Stix and Gorton (1991), which stressed the commonly equivocal nature of the local volcaniclastic (pyroclastic or sedimentary?) deposits.

MARBLE UNITS: PROBLEMS OF IDENTIFICATION AND REGIONAL STRATIGRAPHIC CONTEXT

Regarding past identifications of marble at four locations in the Birch–Uchi greenstone belt (three of which have been discussed above), all are problematic, in different ways:

1. some are probable carbonatized shear zones (e.g., southwest Confederation Lake; South Bay of Birch Lake: Devaney 2001);
2. documentation of lithological details is vague for some presumed marble occurrences (e.g., Narrow Lake, southwest Confederation Lake); and
3. at Woman Lake, 10 cm scale curved forms appear to have been produced by tectonic deformation, and are thus not domal stromatolites (cf. Hofmann et al. 1985).

This may reflect an over-enthusiasm for the identification and correlation of marble units in northwest Superior Province during the 1980s (e.g., Wallace et al. 1986).

If Archean marble units represent stratigraphically condensed sections (i.e., chemical sedimentary horizons which had a very low rate of clastic and volcanic deposition) of (sub)regional extent, this is favourable for the purposes of stratigraphic correlation. If a marble unit is (and was) of only local extent, it will have little or no correlative value; presumably, a) shallow water algal-bacterial mats can accumulate quickly in many basinal settings, including volcanically active areas, to form stromatolitic marble units; and b) volcanic exhalations of CO_2-rich fluids and gas can trigger precipitation of carbonate in both marine and nonmarine aqueous environments. (For example, regionally scattered small marble units could represent horizons in lacustrine or marine sequences of various ages, with no chronostratigraphic correlation amongst them.)

Generally, the correlation of multiple horizons or units between or among stratigraphic cross-sections, rather than the matching of only a single horizon, enhances the reliability of a stratigraphic correlation. Correlation of multiple units is the case in western Uchi Subprovince, where a few Woman assemblage marble units overlie felsic tuff (Wallace et al. 1986). However, given the complexities listed above, the small size of marble units in western Uchi Subprovince (Hofmann et al. 1985; Wallace et al. 1986; Stott and Corfu 1991), particularly their limited lateral extent, and recently posited questions regarding the legitimacy of a "Woman assemblage" at Woman Lake (Rogers et al. 2000), caution and reevaluation of their potential stratigraphic importance are suggested.

EPICLASTIC CONGLOMERATIC STRATIGRAPHIC UNITS

The three epiclastic conglomeratic units described herein are interpreted to have origins similar to the tectono-stratigraphic scenario previously presented for late orogenic strike-slip (pull-apart) basins in the northern Birch–Uchi greenstone belt (Devaney 1997, 1998, 1999a,b,d, 2001), except that:

1. the postarc context is less certain for the Woman Lake conglomeratic unit than for other conglomeratic units in the belt; and
2. the Woman Lake and Sundown Lake conglomeratic units would have been controlled by sinistral (rather than dextral) faulting, given the predominantly sinistral late orogenic faulting in the southern part of the Birch–Uchi greenstone belt (see Devaney 1999a,b, 2001, and references therein).

For the frequently studied Woman Lake area, there is now documentation of more variability of sedimentary facies than was previously appreciated, and the newly recognized west-younging top indications are relevant to any regional structural analyses.

Note, not all Archean polymict conglomeratic units are synorogenic, and ideally such units can have a variety of origins: for example, deposition in a prearc rift basin, or in an intra-arc wrench basin (cf. Hathway 1993), or in postarc early orogenic synthrust piggyback and foreland basins (cf. Devaney 2000). However, for Superior Province, interpretations of deposition of polymict conglomeratic units during stages of late orogenic strike-slip faulting (or wrenching) are most common for Timiskaming-type sequences (Stott and Corfu 1991; Williams et al. 1992, Mueller and Corcoran 1998). Importantly, given recent knowledge of the complex and variable nature of strike-slip faulting in orogenic belts (Nilsen and Sylvester 1995), strike-slip basins were most likely subject to multiple episodes of compression or transpression both during and after their depositional histories (Devaney 1999b,d, 2000, 2001). Thus, a complex, multistage deformation history in a conglomeratic (or other metasedimentary) unit does not necessarily require that the unit be a relatively old deposit; both synarc and postarc deposits may have been multiply tectonized.

In the Birch–Uchi greenstone belt, the late orogenic conglomeratic units are significantly smaller than the synarc volcaniclastic units, which is an expected consequence of orogenic belt development

because of the typically increased degree of structural partitioning over time (e.g., as outlined for the Sioux Lookout belt: Devaney 2000). As discussed above (see "Cromarty Lake Area"), there can be a significant problem of field geology involving the recognition of younger (meta)sedimentary successions overlying older (meta)sedimentary successions, especially if any unconformity between the two is not recognized (e.g., old wacke overlain by young wacke, with nonexposure of the contact). Interestingly, many pull-apart basin conglomeratic units in the Birch–Uchi greenstone belt are adjacent to (bounded by) volcaniclastic units, suggesting that synorogenic strike-slip may have nucleated along and reactivated preexisting weaknesses, such as thinly layered volcaniclastic units and/or deformation zones, in the tectonized stratigraphic section.

RELEVANCE OF STRATIGRAPHIC STUDIES TO MINERAL EXPLORATION

As noted above, regarding the regional stratigraphic context of the South Bay volcanogenic massive sulphide Cu-Zn deposit, both near the mine and regionally, structural complexity and poor continuity of exposure unfortunately strongly limit stratigraphic (volcanic facies and ore deposit models) resolution.

Some workers have suggested a back-arc basin setting for the deposition of the Confederation assemblage, based on geochemical (geodynamic) signatures (e.g., Hollings 1998), but because no active arc versus back-arc (paleo-)basinal geometry or stratigraphic relationships have been demonstrated, the supposed back-arc context might be better considered as intra-arc rifting. Aspects to consider in interpretative analyses of synvolcanic extensional basins and subbasins include: the common association of calderas and normal (extensional) faults; difficulties in identifying synvolcanic faults in subsequently deformed belts; and difficulties in distinguishing intra-arc basins from back-arc basins (Smith and Landis 1995; Marsaglia 1995).

Regarding the potential for mesothermal gold deposits in the Birch–Uchi greenstone belt, interpretations of strike-slip basins such as those described herein imply the regional importance of strike-slip faults (and, at depth, related shear zones), which are commonly thought to have been important in focussing the synorogenic flow of auriferous fluids within tectonized greenstone belts (see discussion and references cited above, under "Present Study and Relevance to Potential Mineralization").

Examination of the gold occurrences in the study area was not part of the present study. Details concerning the geology of the numerous gold occurrences in the Birch–Uchi greenstone belt are summarized elsewhere (Parker and Atkinson 1992). One particularly interesting area of gold occurrences surrounds the former Uchi mine in Earngey Township, between Lost Bay and Uchi Lake, where folded stratigraphic units define a 10 by 4 km sigmoidally shaped region in map view (Thurston et al. 1974; Thurston 1984). Given the late orogenic sinistral offsets common in this (southern) part of the belt (Fyon and Lane 1985; Crews 1999; Rogers et al. 1999; see Devaney 1999a,b, 2001, and references therein), and the similarity in size and outline of this sigmoidal region with the conglomeratic pull-apart basin units in the belt, it is suggested that the sigmoidal region could represent a sinistral transtensional structural domain, a fault releasing bend area (loosely analogous to a large-scale tension gash) and perhaps also the basement of an eroded-away pull-apart basin. Presumably such transtensional faulting localized the distribution of the numerous gold occurrences at and near the Uchi minesite. Testing of this speculative scenario would obviously require detailed structural investigation.

AN EVOLVING REGIONAL STRUCTURAL FRAMEWORK

The early evolution of the western Uchi Subprovince, including the Birch–Uchi greenstone belt, is not well known. Based largely on recently documented geochemical signatures, older assemblages such as the Balmer assemblage may owe their origin to ca. 3.0–2.9 Ga plume-related rift events (Tomlinson et al. 1998; Hollings 1998), and other pre-Confederation assemblages may be of varied origins (accreted oceanic plateaux terranes, arc settings: Hollings 1998). Interpretation of the ca. 2.74 Ga Confederation assemblage as a continental margin (Andean-type) arc sequence at the south margin of the Berens River Subprovince (Stott and Corfu 1991; Stone 1998) is largely confirmed by recent work emphasizing geochemical data and probable intra-arc (or back-arc) rifting (Hollings 1998; Rogers et al. 1999, 2000). Regarding postarc orogenesis, Stott and Corfu (1991) advocated early thrusting followed by wrenching (strike-slip faulting, with local complications: Devaney 1999a,b,d, 2001). Direct evidence for thrusting (Stott and Corfu 1991) is commonly weak, given the tendencies of faults to lie beneath covered intervals and to have been reactivated during later stages of strike-slip faulting. The newly documented relationships between assemblages (Rogers et al. 1999; Sanborn-Barrie et al. 2000) and the revisions to assemblage classifications (Hollings 1998; Devaney 1999b, Rogers et al. 2000) of recent and ongoing studies are refining the tectono-stratigraphic framework of the Uchi Subprovince.

Speculations Regarding Thrust Faulting and the Doubly Vergent Orogen Model

Within the southern Birch–Uchi greenstone belt, the predominantly east-younging Balmer and Woman assemblages (Thurston 1984; Stott and Corfu 1991; plus the proposed Narrow Lake assemblage of Rogers et al. 2000), preserved along the western marginal part of the belt, contrast with the predominantly west-younging stratigraphic units exposed to the east (from Woman Lake to Uchi Lake), consisting of the Confederation assemblage and the presumably younger conglomeratic sequences. (The assessment "predominantly west-younging" is admittedly a broad generalization, which ignores some structural complexities, but it is supported by the top indications recorded by both the present study (Tables 1, 2) and some previous studies (e.g., Thurston 1984).) This pattern of units stratigraphically facing inward towards the axis of the belt resembles that of an asymmetric doubly vergent orogen. (Note the difference between the old-fashioned "synclinorium" models and the newer doubly vergent orogen model (e.g., of Willett et al. 1993).)

The presence of consistent younging directions in thick tectonized successions (homofacing units of Stott and Corfu 1991, p. 192) is a common pattern in Archean greenstone belts, and is, in many cases, suggestive of the thrust stacking of stratigraphic units; where most beds are not overturned, the predominant younging direction is opposite to the thrust vergence direction. Thus, given the above, it is speculated broadly that Confederation assemblage units may be stacked in east-vergent thrust packages, with significant complications owing to folding, intrusions, and late orogenic wrenching. The locations of the supposed thrust faults could have been influenced by the presence (and reactivation) of older extensional faults (e.g., listric normal faults?), which must have developed during the interpreted intra-arc (or back-arc) rifting and Confederation assemblage deposition (Hollings 1998; Rogers et al. 1999). The typically subvertical orientation of strata in the belt implies postthrust compression or transpression, followed by the strike-slip faulting (indenter-related?) reviewed above.

If the scenario of thrust packages within a doubly vergent orogen is valid, the orogen (i.e., the southern Birch–Uchi greenstone belt) would appear to have been pinched between two blocks of sialic crust, the older Trout Lake batholith to the west and the undated Jeanette Lake granitic complex to the east (*see* Figure 1). (Regarding the hypothesized presence of older crust in the Jeanette Lake complex,

suggested by Devaney (1999a,b, 2001), this unproven inference is based on the presence of two potentially similar areas of 2.8 Ga crust farther to the east, in central Uchi Subprovince (Stott and Corfu 1991).) At a larger scale, and as a very broad generalization, it has been proposed that the western Uchi and English River subprovinces together form a doubly vergent orogen pinched between microcontinental blocks (Devaney 1999a, Figure 18.3), with the Uchi Subprovince as the retrowedge area and the English River Subprovince, a tectonized remnant ocean basin succession (*sensu* Ingersoll et al. 1995) as the prowedge or axial zone area. Thus a smaller-scale doubly vergent pattern may complicate a larger doubly vergent pattern. Late orogenic wrenching, the result of large-scale regional transpression (Stott and Corfu 1991; Corfu et al. 1995) and suggested deformation of the Birch–Uchi greenstone belt against an obstacle-like promontory or indenter (*see* Figure 1b; Devaney 1999b, 2001), presumably would have overprinted or enhanced the doubly vergent patterns.

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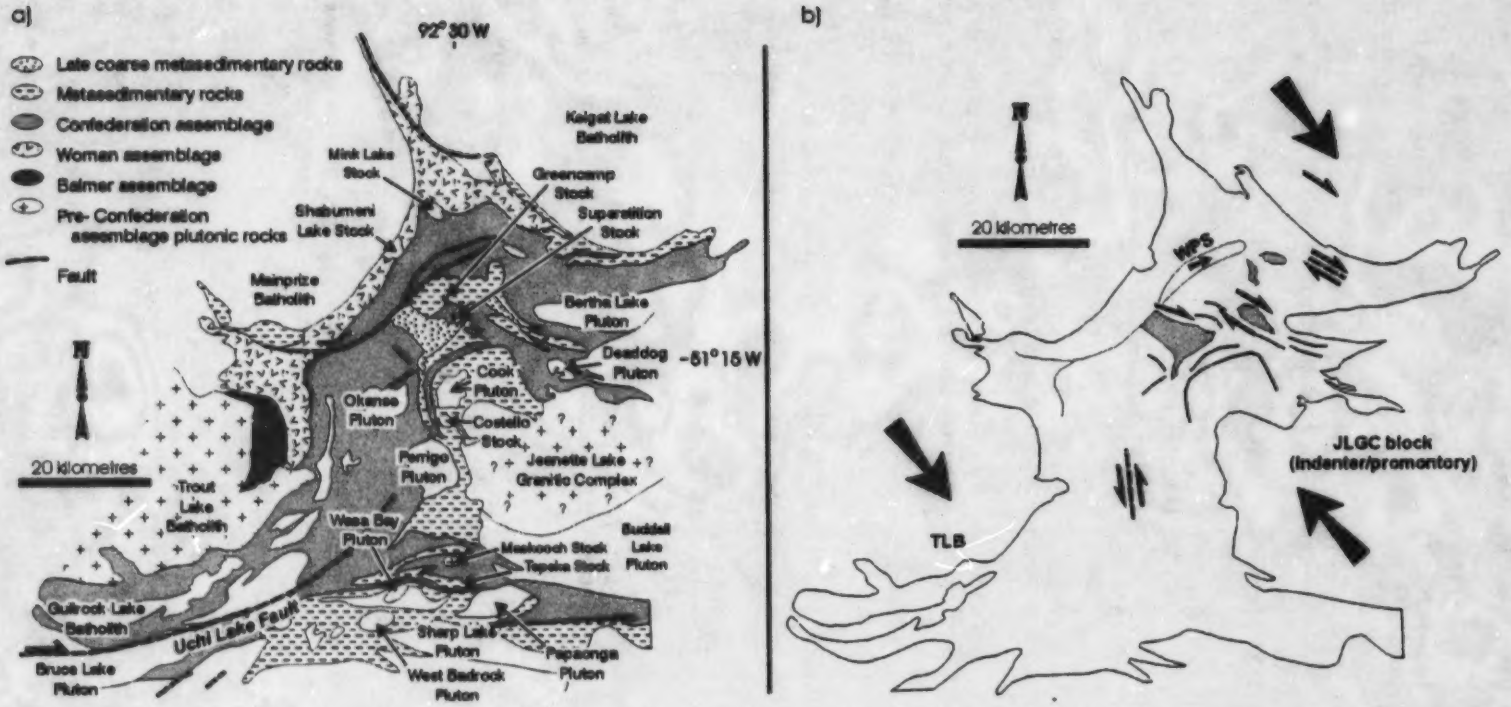

Figure 1. Geological map (a; after Stone 1998, Figure 5) and interpretative cartoon map (b) of late orogenic structural components of the Birch–Uchi greenstone belt and surrounding areas. In b: large arrows indicate northwest-southeast regional compression and/or transpression, WPS, Western Peninsula Scholle; JLGC, Jeanette Lake Granitoid Complex; TLB, Trout Lake Batholith; and stippled areas are conglomeratic dextral pull-apart basins (see Devaney 1999a,b, 2001).

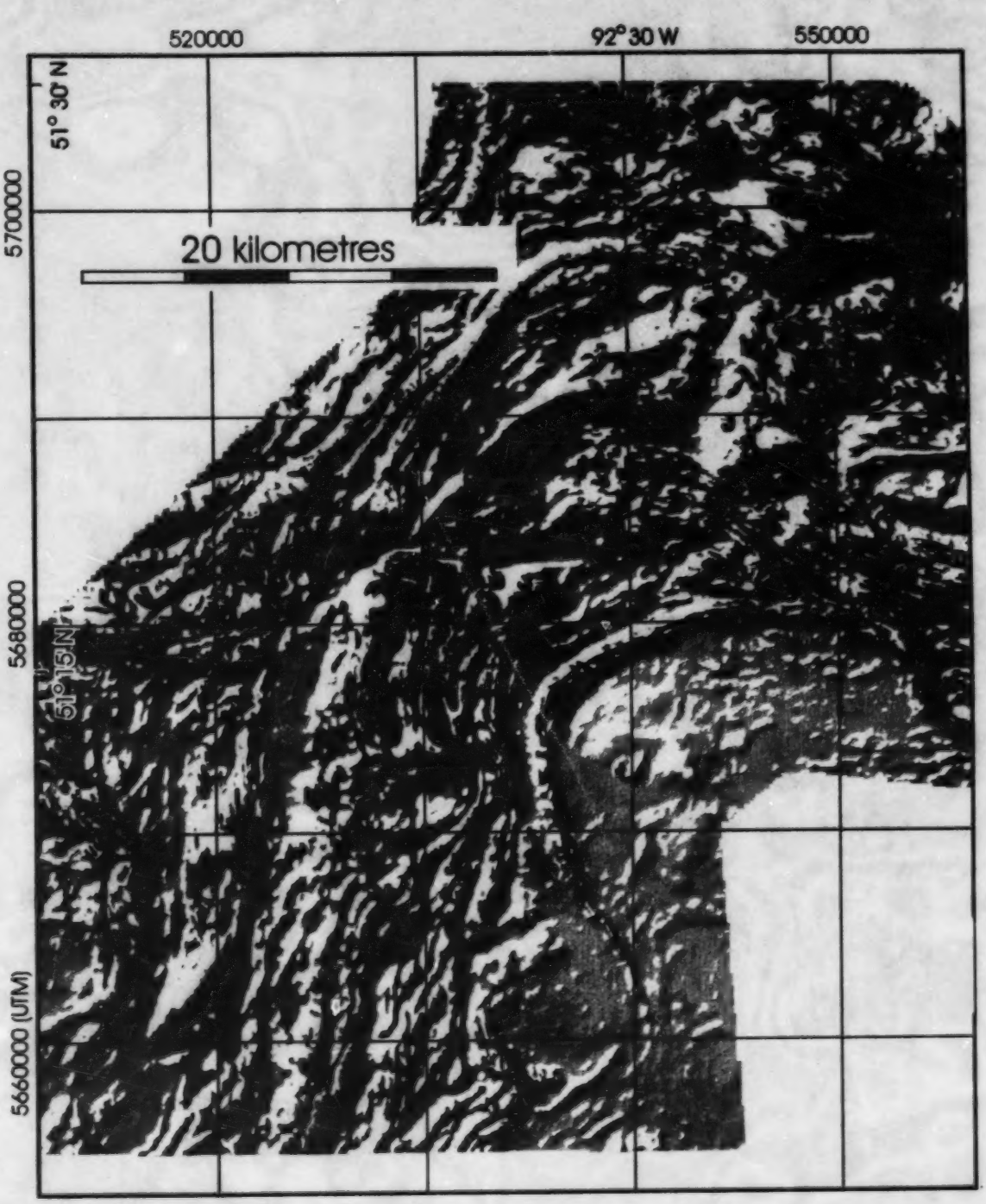

Figure 2. Shaded relief total field aeromagnetic pattern of the Birch–Uchi greenstone belt (from OGS 1997); light tones have higher magnetic susceptibility (e.g., metabasalts), dark tones have the least magnetic susceptibility (e.g., metawackes, granitoids); compare with Figure 1.

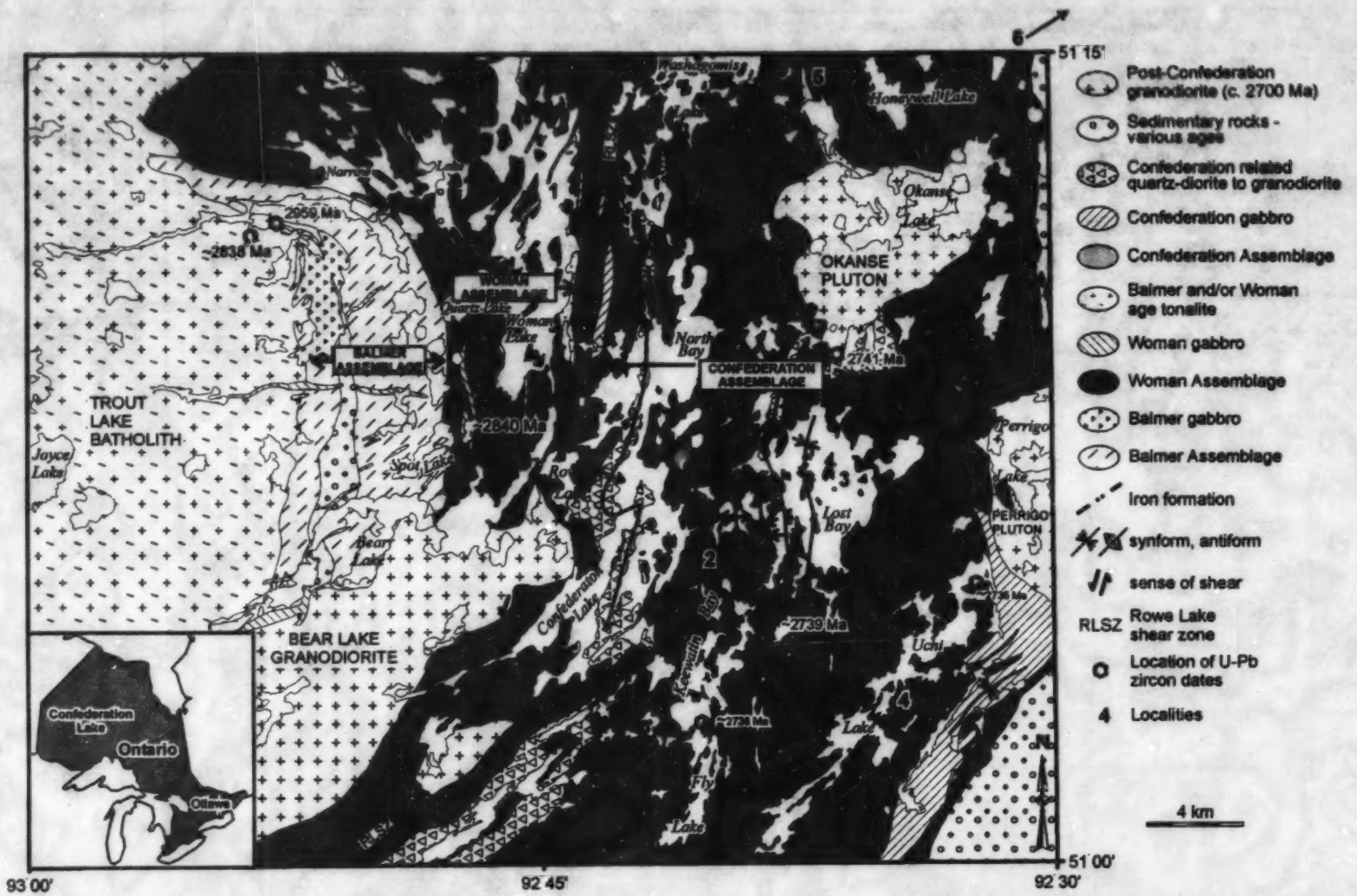

Figure 3. Geological map of the southern Birch–Uchi greenstone belt (modified from Rogers et al. 1999, Figure 1), with locations 1 to 6 discussed in the text. 1, Woman Lake (Narrow Lake is adjacent to the northwest); 2, South Bay, Confederation Lake; 3, Lost Bay, Confederation Lake; 4, Uchi Lake; 5, Sundown Lake; 6, Cromarty and Bertha lakes (off map to northeast).

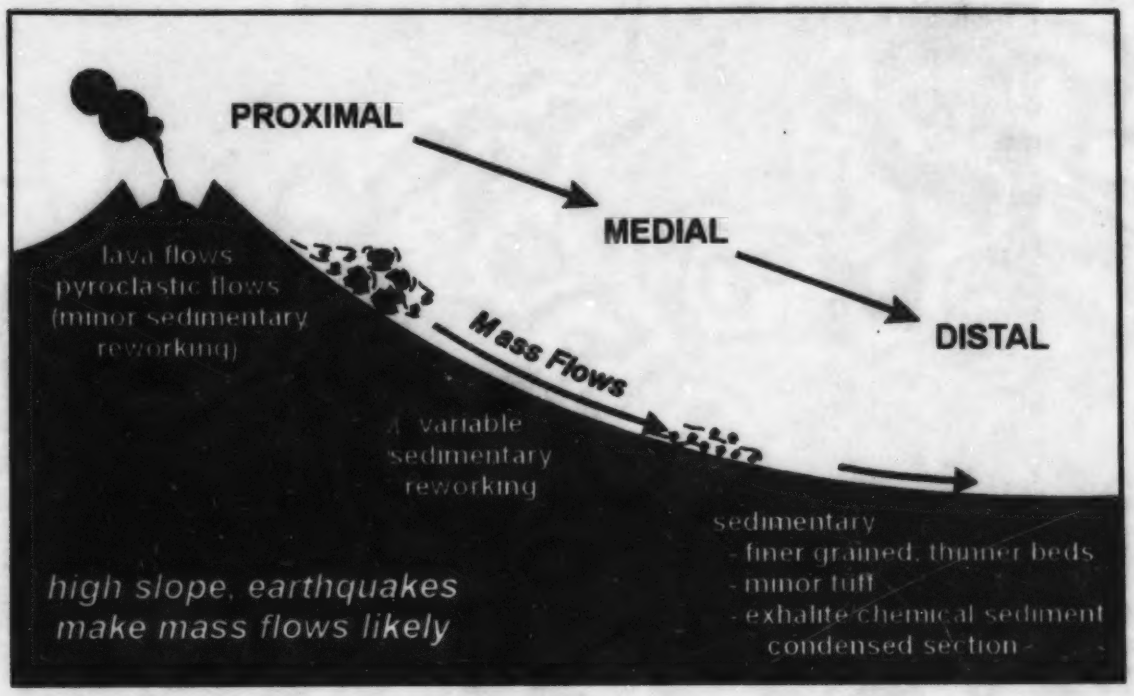

Figure 4. Model of a proximal volcanic to distal, mostly sedimentary facies transect. In such a depositional setting, sedimentary reworking of proximal pyroclastic material would be expected, and identification of such reworking would depend largely on stratigraphic context (the recognition of the proximal, medial and distal parts of individual units, members or other distinct layers).

Photo 1. Very coarse (bouldery), poorly sorted, crudely bedded, clast-supported, polymict and strained conglomerate. Central Woman Lake.

Photo 2. Fining- and thinning-upward sequence of: fine pebble conglomerate, pebbly sandstone, thinly bedded coarse sandstone, and laminated dark finer sandstone. This is capped by pebbly sandstone and coarse poorly sorted conglomerate (note cobble to right of scale card). Central Woman Lake.

Photo 3. Crystal lapilli-tuff, also known as the local quartz-feldspar "porphyry." Note the angular outline of some of the tiny clasts. South Bay minesite.

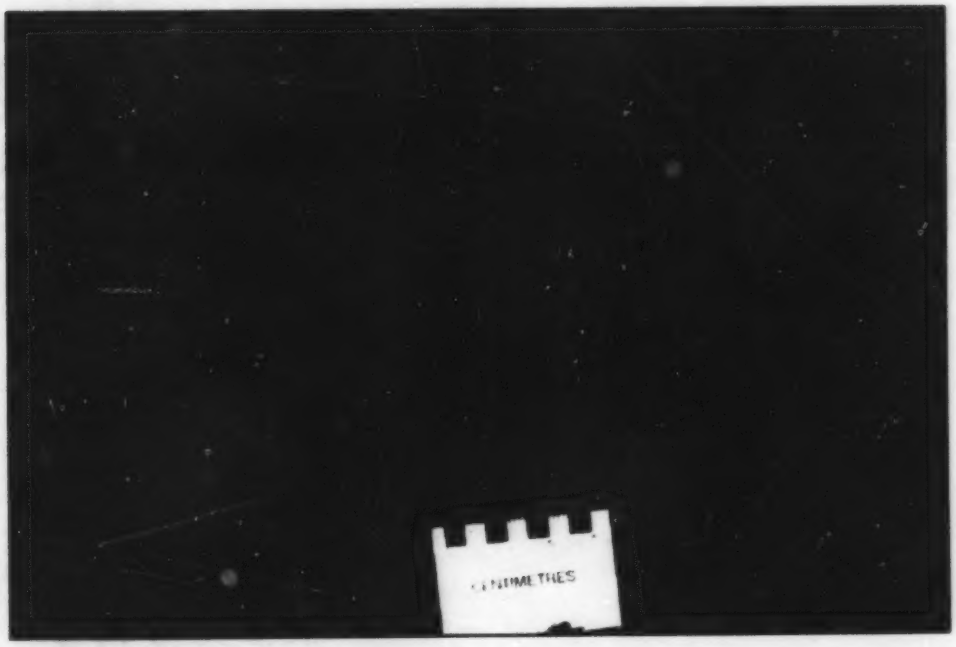

Photo 4. Flow banding in rhyolitic lava, partly outlined by light spherultic texture (large devitrification nodules) set in a dark matrix. Small lake near (northeast of) junction of South Bay mine road and power line.

Photo 5. Variety of flow banding (note folded layers with light spherulitic texture in dark matrix) and (synvolcanic) breccia fabrics, reflecting variations in the viscosity of the original lava flow(s). (Same outcrop as in Photo 4.)

Photo 6. Dark mudstone intraclasts in tuff. East shore of South Bay, about 1 km south of South Bay minesite.

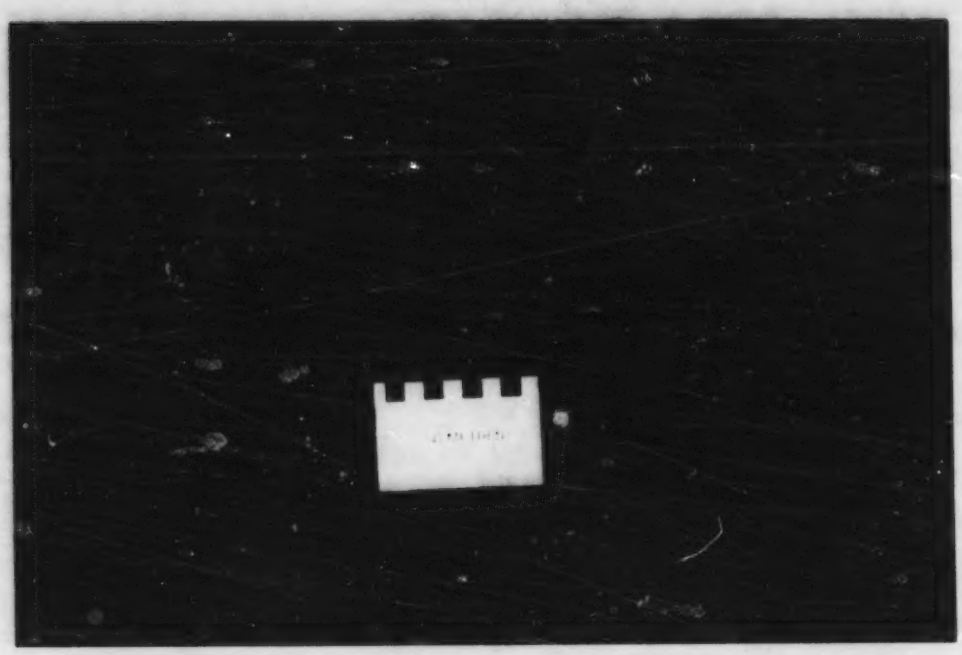

Photo 7. Tightly packed, commonly angular clasts in lapillistone/conglomerate. Note the polygonal to diamond-shaped outlines of some of the clasts. Eastern Lost Bay.

Photo 8. Laminated to thinly bedded sandstone with a cross-laminated bed. About 2 cm below fingertip, ripple low-angle foresets are concave up, tangential, and give an apparent paleocurrent to the right. The way up is agreement with the normal (fining up) graded bedding seen elsewhere in the same outcrop. Western Lost Bay.

Photo 9. Tectonically transposed laminae in deformed wacke-siltstone. Uchi Lodge, west shore of Uchi Lake.

Photo 10. Penecontemporaneous (soft-sediment) deformation fabrics include folded laminae (e.g., left of scale card), loaded bed contacts (note prominent upward-pointing "flame structure" about 3 cm above upper left corner of scale card), and brecciated small slabs of strata (below scale card). Bay along east shore of central Uchi Lake.

Photo 11. Penecontemporaneous (soft-sediment) brecciation of competent thin beds and laminae and centimetre-scale dikes and sills that formed via flowage of the sandy matrix material between the brecciated slabs and fragments. (Same outcrop as in Photo 10.)

Photo 12. Between conglomerate beds, sandstone interbeds (across middle of photo) contain a concave-up scour (at right) which truncates a pebble band. Sundown Lake.

Photo 13. At centre of photo, scouring at the base of a conglomeratic bed produced thinning and truncation (to the left) of the darker, finer, underlying sandstone bed. Sundown Lake.

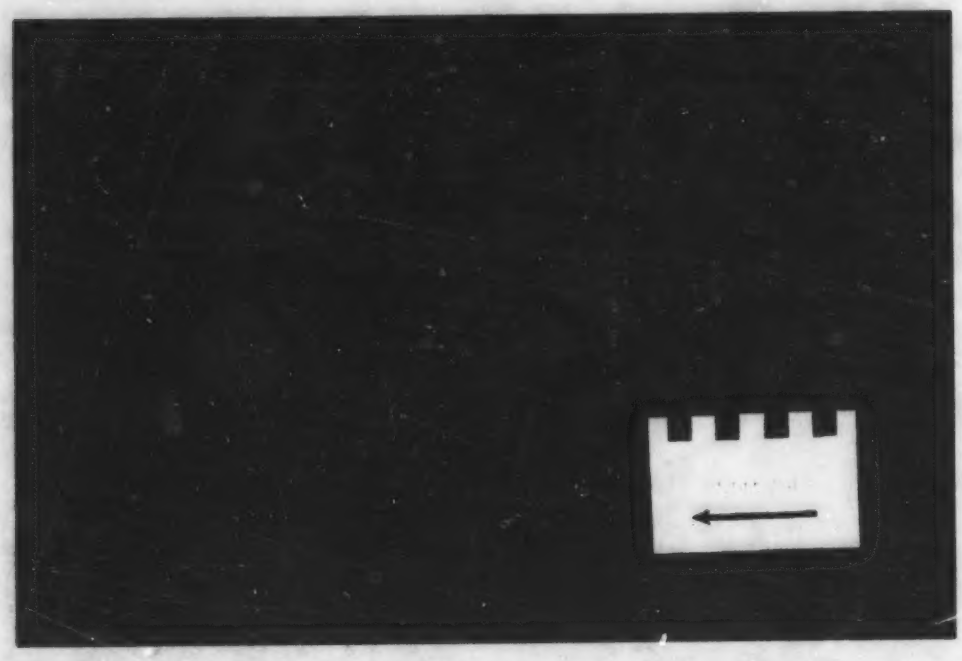

Photo 14. Thick graded beds (tops to left), with "coarse-tail" concentrations of the coarsest grains at the bases of the beds, and tonal grading upward to darker muddier sandstone. (Same outcrop as in Photo 13.)

Photo 15. An example of the distinctive spherulitic clasts common in conglomerate at Sundown Lake and very similar ("apparently identical") to the spherulitic fabrics seen in outcrops of lava facies along the east shore of Sundown Lake.

Table 1. Table of top indications from the present study of selected stratigraphic units in the southern Birch–Uchi greenstone belt.

Location, legend code on map*	Outcrop#, str/dip or orientation	Structure showing top indication	Comments
Narrow Lake area			
4abdijGH	368, 350/90 to 5/ (top E(?))	GR(?)	
4cdi	372, top E(?)	RI(?)	
4bdijGHJ	380, 327/80	SC, GR, LO, SS	
Woman Lake area: conglomerate			
4abijlHK	292, 185/ (top W)	XB/RI	Subtle; tangential toesets
4abdijkFGN	293, top W	GR, FUS, SC(?), RI	Vaguely graded sandstone laminae; Photo 2
4abcdijFHJR	295, 170/ (top W) and 330/70 (top E)	FUS to W; GR to E	
4abijkFGHKNR	296, 190/ (top W)	SC	Micro-channel
4abijlHJR	298, 195/ (top W)	SS, GR	Arkosic sandstone
4abGHJ	301, 50/ (top SE?)	GR	
4ab	308, top NE	LO	
Woman Lake area: wacke			
4cd	300, 356/75	GR	
4bcdijkG	305, 340/70 to 10/70	GR, SS	
4cijk	306, 0/ (top E)	GR	
4cijHJ	315, 26/85(ot)	GR	Grading preserved inside shear lenses
4acHR	316, 140/ (top SW)	GR	Structural facing to SW
4ciHJ	317, 30/80(ot)	GR, SS	Sheared-up beds
Woman Lake area: other units			
(Shanty Bay) 4acdijGHJKLN	288, top NE	SC, RI	
(intermediate volcaniclastic unit) 2fgijM	312, top N(?)	GR, SC	
Lost Bay area			
3fgij	23, 350/70(ot)	GR, LO, RI, SS	Inverse grading also; Photo 8
3fiHJ	70, 255/ (top N)	GR	
3fgjklFKR	74, 210/ (top W)	GR	Inverse grading also
3fgijFHJ	75, 220/ (top NW)	GR, SC	Inverse grading also
3fij,5ci	81, top SW	GR	In BIF, with S-folds
2gH,5ij	97, top SW	GR	
2fgjk	100, 180/90	GR	
2fgijG	101, top W	GR	

Table 1. *Continued.*

Location, legend code on map*	Outcrop#, str/dip or orientation	Structure showing top indication	Comments
Lost Bay area, cont'd			
2fgikJ	102, 180/90	GR	
2fg,l	103, 210/90	GR	
3fgijklHLQR	118, 30/80(ot)	GR	
4cijHJ	381, 03/ (top W)	GR	
3fij	382, 345/ top W)	GR, LO	Good soft-sediment folds
3fgijHJ	387, 165/ (top W)	GR	Inverse grading also; good soft-sediment folds
3fgijHJR	395, top W	GR	Inverse grading also
3fghijFGKNQR	397, top W(?)	XB(?)	
3fijHJ	398, top W	GR	
Uchi Lake area			
3f(4cd)iHJ	214, 208/ (top W)	LO	
4cdjJ	219, 335/ (top W)	GR	
3f(4cd)jJ	232, 335/80	GR	Vague grading
4cdijI	235, top W	GR(?)	
4cdi	240, 70/ (top SE)	GR	Only one graded bed
4cdij	248, 190/90	GR	
4cijkIJ	250, 210/90	GR, LO	Superb soft-sediment deformation features (e.g., Photos 10, 11)
4cdJ	259, top W(?)	GR(?)	
2g(4cd)ijHJ	262, 220/ (top NW)	GR	
3f(4cd)ij	265 (Uchi Lake Lodge), 54/ (most tops NW)	GR	Highly deformed (e.g., transposed layering)
4cj	266, top NW	GR	
4cj	277, , top NW	GR	
4c	278, 30/80(ot)	GR	
4c	279, top NW	GR	
4c(3f)j	280, top NW	GR, SS	
Sundown Lake area			
4abjkG	121, top W(?)	SS(?)	
4abijklmGHJ	122, 180/90	XB/SC, GR	Photo 12
4abijklGHIJKN	124, 150/90	GR, SS, SC, RI, XB	Photos 13, 14
4ab	125, top W	SS	

Table 1. *Continued.*

Location, legend code on map*	Outcrop#, str/dip or orientation	Structure showing top indication	Comments
Cromarty Lake area			
4cdij	160, top S	GR	
4cdijkHIJ	166, 155/70	GR	
4cdijJ	167, 130/75	GR	
4cdfHJ,3fgR	176, top SW	GR	
4abjkH	181, top SW	FUS	
4abjklHJ	182, top SW	XB(?), SS	

FUS, fining-upward sequence; GR, graded bedding; LO, load structure; ot, overturned strata; RI, rippled (cross-laminated); SC, scour structure; SS, sharp-soled (sharp-based) beds; STR/DIP, strike and dip measurements (using right-hand rule); XB, cross-bedded; N, NE (etc.)= north, northeast (etc.).

** For legend codes, see page 45 and Devaney and Crews, in press.*

Legend for Table 1

Rock Codes

8 Felsic to Intermediate Intrusive Rocks
("9" if late, post-tectonic)
8a Granite
8b Granodiorite
8c Tonalite
8d Diorite
8e Pegmatite
8f Aplite
8g Quartz
8h Porphyritic

7 Mafic Rocks
7a Diabase
7b Gabbro
7c Amphibolite

6 Felsic to Intermediate
(Meta-)Intrusive/Subvolcanic Rocks
6a Quartz porphyry
6b Feldspar porphyry
6c Quartz-feldspar porphyry

5 Chemical Metasedimentary Rocks
5a Chert
5b Chert and magnetite
5c Magnetite
5d Hematite
5e Pyrite

4 Clastic Metasedimentary Rocks
4a Conglomerate
4b Arenite
4c Wacke
4d Argillite/siltstone
4e Slate
4g Schist

3 Felsic Metavolcanic Rocks

2 Intermediate Metavolcanic Rocks

1 Mafic Metavolcanic Rocks
1a Massive
1b Pillowed
1c Amygdaloidal/vesicular
1d Variolitic/spherulitic
1e Porphyritic
1f Tuff
1g Lapilli-tuff, lapillistone
1h Tuff-breccia

Textural and Mineralogical Codes

i....laminated (<1 cm thick)
j....thinly bedded (1-10 cm thick)
k...medium bedded (10-30 cm thick)
l.....thickly bedded (>30 cm thick)
m...garnet porphyroblasts
n....(other) porphyroblasts
o....gneissic
q....mineral clots
r....chloritic schist
w...epidote
z....quartz-sericite schist
A...aphanitic
B...fine-grained (<1 mm)
C...medium-grained (1-5 mm)
D...coarse-grained (>5 mm)
E....pegmatoid (>1 cm)
F....boulders, cobbles, blocks, bombs (>64 mm)
G...pebbles (2-64 mm)
H...coarse-, very coarse-grained (0.5-2 mm)
I.....medium-grained (0.25-0.5 mm)
J....very fine-, fine-grained (0.06-0.25 mm)
K...clast-supported framework
L...matrix-supported
M..monolithic (oligomictic)
N...heterolithic (polymictic)
O...pillow breccia
P....hyaloclastic
Q...pumiceous clasts
R...porphyritic clasts
S...mixed composition: mafic matrix,
felsic/intermediate clasts
U...(other) volcanic breccias
V...tectonic breccias
W..vein
X...dike
Y...sill
Z....xenoliths

Table 2. Summary statistics of top indications from the present study of selected stratigraphic units in the southern Birch–Uchi greenstone belt.

Area	Number of outcrops with top indications	Number of outcrops with tops to west	Number of outcrops with tops to east
Narrow Lake	3	0	3
Woman Lake conglomerate unit	7	5 (one is to both east and west, in different facies)	2
Woman Lake wacke	6	3	3
Woman Lake: other	2		1 (plus 1 to N)
SW arm of Confederation Lake	0		
South Bay mine unit, incl. Fly Lake area	0		
Lost Bay	17	16 (plus 1 to N)	
S of Lost Bay (power line section)	3	3	
Uchi Lake	15	14	1
Sundown Lake conglomerate unit	4	4	
Cromarty Lake conglomerate unit	6	6	
Bertha Lake	0		
(TOTALS)	63	51	10 (plus 2 to N)

Metric Conversion Table

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
		LENGTH			
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
		AREA			
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
		VOLUME			
1 cm^3	0.061 023	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.307 951	cubic yards	1 cubic yard	0.764 554 86	m^3
		CAPACITY			
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
		MASS			
1 g	0.035 273 962	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 747	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 622 6	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311 3	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 90**	t
		CONCENTRATION			
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

	Multiplied by	
1 ounce (troy) per ton (short)	31.103 477	grams per ton (short)
1 gram per ton (short)	0.032 151	ounces (troy) per ton (short)
1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in co-operation with the Coal Association of Canada.